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**Michael Inglis**

**Making sense of physics: student  
teachers' experiences of a physics  
Subject Knowledge Enhancement course**

**Doctorate in Education (EdD)**

**The Open University**

**31<sup>st</sup> October 2014**

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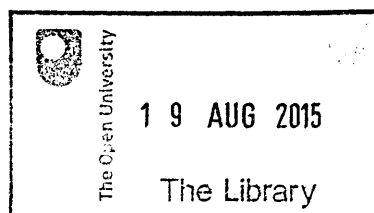
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## Abstract

Concerns about the inadequate supply of secondary school physics teachers in England are widely reported. One attempt to increase supply is the Subject Knowledge Enhancement (SKE) course, intended to develop the physics subject knowledge of non-physics graduates so they can enter an Initial Teacher Education (ITE) course to become physics teachers. Little attention has been given to examining SKE students' experiences of engaging with a subject they last studied at school. In this study, individual semi-structured interviews and focus groups are used within an interpretivist methodology to explore the cases of seven physics SKE course students in one English university. The research is informed by social models of subject knowledge development within a community of practice, with the aim of exploring the students' conceptualisations of subject knowledge and how these develop during ITE, and what they experience as significant for their subject knowledge development.

Data analysis is exploratory, utilising grounded theory approaches. Key findings are: students hold diverse beliefs about physics as a body of factual content knowledge; they prioritise the development of confidence at explaining physics as an affective criterion for sufficient subject knowledge; they perceive influential messages about the nature of physics subject knowledge for teaching from the modelling of practice by course tutors; and, interaction with peers and tutors is highly valued, especially during peer-teaching activities where students take it in turns to 'teach' physics to each other. Viewing the SKE course as a *community of practice* (Wenger, 1998) reveals the importance of sustained interaction, for facilitating development of subject understanding, and the role of ITE tutors for brokering students' entry into the communities of practice of physics and of physics teachers. This research provides support for ITE policies that emphasise the value of university-led subject knowledge development by experienced teacher educators.

## 1. Introduction and context

Nick        I'm not a scientist, no way, because I'm a science *teacher*; it's something completely different.

This thesis explores the conceptualisations and experiences of a group of student secondary school physics teachers during a pre-service Subject Knowledge Enhancement (SKE) course. Physics SKE courses are one attempt to address the insufficient supply of new secondary school physics teachers (Institute of Physics, 2010). Such courses take graduates without a physics Bachelor degree and aim to develop their physics subject knowledge so they can become secondary school physics teachers. SKE students' experience of engaging with physics for the purposes of preparing to teach it is an under-researched area. I will show that these students bring to the course diverse ways of conceptualising physics subject knowledge. I will also show that central to the process of learning physics is interaction with peers and the role of course tutors in communicating messages about physics subject knowledge, and brokering entry into the practices of the community of physics teachers.

### 1.1 Thesis structure

The remainder of this chapter will explain how the research questions emerged from my professional background and practice as a teacher educator. The research context of ITE and SKE courses in England, and how the SKE course model is operationalised in the researched institution, will be outlined. I will also outline Wenger's conception of communities of practice (Wenger, 1998) as a theoretical lens through which the SKE course can be viewed.

In chapter 2, I will review key literature related to the research questions on student experience of SKE courses and teacher subject knowledge development.

In chapter 3, the methodological stance and research design will be discussed. Details of the data collection methods used will be explained along with the approach to data analysis.

Chapter 4 will present data from each participant, as individual cases of students on the researched SKE course, and from the focus groups.

Chapter 5 will present the results of analysing the participants as a group with a shared experience of an SKE course. Key findings will be discussed in response to the research questions.

In chapter 6, the main conclusions will be discussed along with implications for policy and professional practice. I will also present my reflections on the conduct of this research and how it has informed my practice as an ITE tutor and novice researcher.

## **1.2 Background and research questions**

When I studied to become a secondary school physics teacher little time was devoted to exploring the nature of physics subject knowledge. My PGCE course (in common with many others) started with a subject knowledge audit: a mock exam using GCSE-level physics, chemistry and biology questions. I was then expected to use the audit to address my subject knowledge needs unaided, a common experience for student science teachers who find they are “left to their own devices” (Lock and Soares, 2006, p.33) to develop their subject understanding. I did not question the value of this auditing approach and it did not even occur to me to ask what physics subject knowledge *is*. My view of physics knowledge was based on experience of learning physics at university and as a geophysicist in the oil industry before I became a teacher: physics consisted of a body of uncontested facts to be learned and skills to be honed through individual effort. I also held a firm belief that a Bachelor degree in physics was a prerequisite for being an effective physics teacher. What seems remarkable to me now is not that I had those beliefs (they were shared by many of my fellow PGCE students), but that my views were left unarticulated and unchallenged as I prepared to become a teacher.

After several years as a school physics teacher I joined Albion University in England (Albion is a pseudonym) as a teacher educator. As well as teaching PGCE students, I became involved in the development and teaching of a physics Subject Knowledge Enhancement (SKE) course. This course was intended to develop the physics subject knowledge of non-physics graduates who wanted to go on and become physics teachers. Crucially, the course funding model allowed less than ten hours of student contact time per week, which added to my initial ambivalence about an assumption of the course: that non-physics graduates can become effective physics teachers after a short course in physics with limited teaching time. The wide range of SKE student Bachelor degree backgrounds, and the impossibility of teaching explicitly the entire school physics curriculum in the time available, forced my colleagues and I to think afresh about the type of support needed by these students. More importantly, my initial ambivalence about the course led me to reflect critically on the nature of physics subject knowledge for teachers and the “accepted wisdom” (Kind, 2009a, p.1531) that a Bachelor degree in physics is necessary to teach it effectively. From the birth of the SKE course a question I wanted to answer has been: how can the SKE course design, and my practice as a SKE course tutor, improve to meet the needs of the students? To answer this question, I needed to develop insights into the SKE students’ experiences of learning physics and their self-constructed models of what constitutes physics subject knowledge. This has driven the development of this research, with which I am trying to answer these questions:

RQ1 What are physics SKE students’ conceptualisations of physics subject knowledge for teachers?

RQ2 How do these conceptualisations develop during ITE?

RQ3 What do the students experience as significant for their subject knowledge development?

### 1.3 Initial Teacher Education in England

To be awarded Qualified Teacher Status (QTS) and become a teacher in maintained schools in England (state schools which are controlled by Local Authorities), student teachers must meet a suite of government-prescribed Teachers' Standards (Dept. for Education, 2014a and 2011). The current Standards were introduced in 2012 and specify the minimum skills and knowledge required by all teachers.

The specification of teachers' subject knowledge has varied with each version of the Standards. In 2002 the subject knowledge requirement was that a teacher must have:

a secure understanding of the principles, concepts and skills underpinning their specialist subject(s) at a standard at least equivalent to degree level... (Teacher Training Agency, 2001, p.9)

When the Standards were changed in 2007 subject knowledge was addressed by Standard Q14, which stated that students must have:

secure knowledge and understanding of their subjects/curriculum areas and related pedagogy to enable them to teach effectively across the age and ability range for which they are trained (Training and Development Agency for Schools, 2007)

The 2007 Standards omitted any reference to requirement for subject-specific knowledge at Bachelor degree level. The rationale for the change was unclear, but it opened the way for teachers to enter the profession without a Bachelor degree in the subject to be taught, possibly in response to shortages of teachers in certain subjects. Following implementation of revised Standards in 2012, subject knowledge is now covered by Standard 3, which states that a teacher must "demonstrate good subject and curriculum knowledge" (Dept. for Education, 2011, p.11), and specifically must:

- have a secure knowledge of the relevant subject(s) and curriculum areas, foster and maintain pupils' interest in the subject, and address misunderstandings
- demonstrate a critical understanding of developments in the subject and curriculum areas, and promote the value of scholarship (Dept. for Education, 2011, p.11)

Subject knowledge is now described as “knowledge of the relevant subject(s)” with again no reference to Bachelor degree level, although the government specifies elsewhere that teachers must have a Bachelor degree or equivalent (Dept. for Education, 2012a, statement C1.2). No model of teacher subject knowledge is articulated in the Teachers’ Standards and, as I will discuss in chapter 2, attempting to specify teacher subject knowledge and its development is problematic.

In 2012 the government allowed academy schools (state-funded schools, but free from local government control and able to set their own curriculum and teachers’ pay & conditions) to employ people without QTS as teachers (Dept. for Education, 2012b). This development suggests a government view that teacher professional knowledge can be derived solely from experience, or as one Headteacher voiced, that “teachers are born not made” (Dept. for Education, 2012b). In most of the international educational research literature the formalised system for preparing new school teachers is referred to as *pre-service education* or *pre-service training*. In the English pre-service context, two terms are in common use: *initial teacher training* (ITT) and *initial teacher education* (ITE). The distinction between ITT and ITE is philosophical rather than official. The widespread use of the term ITT in government discourse suggests a view of teaching as a set of skills that can be taught by a knowledgeable ‘expert’. This can be characterised as an apprenticeship model of ITT or a “weak model of teacher professionalism” (Taber, 2007, p.4), where what is considered to be effective practice for teachers is researched or determined by others. There has been much criticism of the ‘training’ view of teacher development (Tripp, 2012; Corrigan et al., 2011; Ellis, 2010; Eraut, 1994). My view is that the growth of a new teacher as an autonomous professional, who can evaluate appropriate courses of action in situations with conflicting demands (such as a classroom), requires an ability to reflect and to use educational research to critically inform practice (Taber’s “strong model” of professionalism (2007, p.6)). ITE is an unofficial term often used by educators to capture this latter model and is the term I have used throughout this research.

A range of ITE routes to QTS are available, via university-led (undergraduate and postgraduate) or school-based programmes (Dept. for Education, 2013). Most graduates who gain QTS to become secondary school teachers in England do so via a Post-Graduate Certificate in Education (PGCE) course (71% with the remaining 29% gaining QTS via school-centred or employment-based routes) (Smithers et al., 2013). A full-time PGCE takes place over an academic year and is run by a university in partnership with secondary schools. The government specifies that at least 120 days of a PGCE course must consist of school-based experience, divided between two or more schools (Dept. for Education, 2012a). During school-based placements, student teachers take on an increasing proportion of a full-time teacher's timetable with the support of a school-based mentor, who is usually an experienced teacher in the subject department. The university-based part of the PGCE course (60 days) is led by teacher educators and covers subject-specific pedagogical issues (such as how to address children's misconceptions in science), general pedagogical knowledge (such as principles of assessment) and the development of subject knowledge. It is the limited time available for this last aspect of subject knowledge development that tends to present the greatest challenge for teacher educators, especially as school-based mentors usually do not have time to support student teachers to consolidate subject understanding, or do not see this as part of their role (Lock et al., 2011; Williams and Soares, 2002). Even those mentors who do have time to provide subject knowledge support sometimes have their own subject misconceptions (Ramlo, 2012; Halim and Meerah, 2002; Preece, 1997). This becomes especially significant when student teachers are required to teach outside of their science specialism, which is common when teaching at Key Stage 3 (age 11-14) and, in some schools, at Key Stage 4 (age 14-16) (House of Commons Children, Schools and Family Committee, 2010; Bishop and Denley, 1997).

## **1.4 Subject Knowledge Enhancement (SKE) courses in the English ITE system**

Debates about the role of a teacher's Bachelor degree background in effective teaching have a particular significance in the area of secondary school physics education due to the on-going crisis in recruitment and retention of new physics teachers (Hillier et al., 2013; Institute of Physics, 2010). Over 500 secondary schools in England do not have a single specialist physics teacher, and despite government recruitment campaigns, only 19% of secondary school science teachers are physics specialists (Gatsby Foundation, n.d.; Smithers and Robinson, 2008; Moor et al., 2006; Institute of Physics, 2001). Over 30% of student physics teachers do not have a Bachelor degree that consists of 50% or more of physics content, with many having less (Lock et al., 2011).

One government initiative to address the recruitment shortfall in key subjects has been funding since 2008 for extended Subject Knowledge Enhancement (SKE) courses (Dept. for Education, 2014b). Physics SKE courses were developed from Physics Enhancement Programmes, which were piloted from 2004 (Shepherd, 2008; Ireson and Twidle, 2004). An SKE course takes graduates with little or no physics at Bachelor degree level and supports them to develop their physics understanding so they can enter a physics PGCE course. Student teachers must have a place on a PGCE course before they can apply for an SKE course, with the PGCE course tutors specifying to potential candidates whether a pre-PGCE SKE course is necessary. SKE courses are run by universities (either by physics departments or by teacher educators based in an education department or equivalent), schools and by specialist teacher professional development providers, such as Science Learning Centres. A wide range of course structures are in operation and durations range from 4 to 36 weeks (Gibson et al., 2013).

## **1.5 The Albion University SKE course**

This EdD research involves the case of one particular SKE course that has been running at Albion University since academic year 2008/9. Conceived and taught from the beginning by the PGCE team, the course was created to be equivalent to Level 6 on the National Qualifications



Framework (Ofqual, 2012) and to run from mid-September to late-May. There are three components to the course structure and three components to the course assessment that are significant for the purposes of this research (Fig. 1).

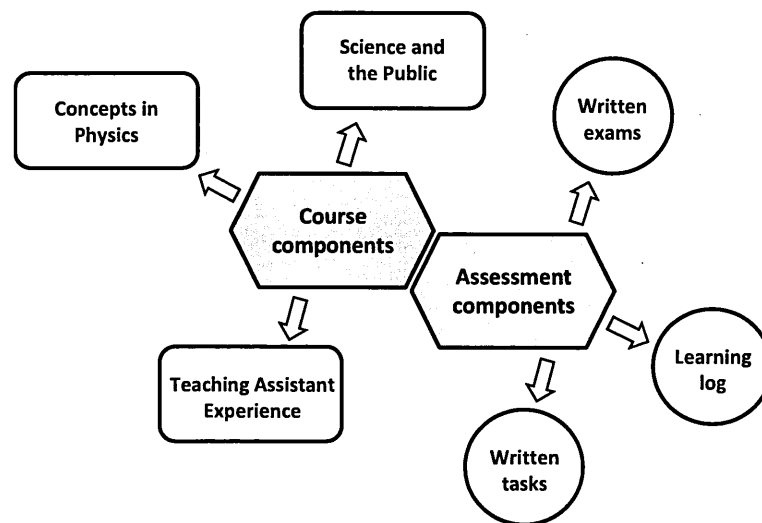


Fig. 1: Key components of the Albion University Physics SKE course

### 1.5.1 Course components

A module I have called *Science and the Public* (this is a pseudonym to protect the identity of the research site institution) supports students to explore the relationship between scientific advances and their impact on people and society. Students research topics such as *nanotechnology* and *CERN and the large hadron collider project* and then present back to the class about the science involved. They also examine issues such as how decisions are made about spending public money on pure research and its unforeseen effects, such as the development of the World Wide Web from work carried out at CERN. In order to give the SKE students some experience of placing their physics knowledge in the context of children's learning, a two-week placement in a school science department is arranged near the end of the course. This *Teaching Assistant Experience* enables students to see the daily work of science teachers and observe the attitudes and misconceptions held by children during physics lessons. This placement experience is not assessed and is not a formal requirement of DfE funding for the SKE course. Its existence came about from the importance placed on school-based experience by the teacher educators

involved in the SKE and PGCE courses. The remainder of the SKE course consists of a group of modules I have collectively called *Concepts in Physics*. These modules cover the school physics curriculum content during formal teaching sessions, including investigative work and the development of laboratory skills.

### **1.5.2 Assessment components**

Students' achievement on the SKE course is assessed in three ways. There are *written examinations* consisting of A-level physics questions. At frequent intervals the students have a range of different types of *written tasks* to submit. These include: problem-solving questions on physics in the style of A-level exam questions; laboratory reports where investigative practical activities are written-up in the style of a scientific report; and, the production of a chapter for a hypothetical physics textbook aimed at A-level students, where the SKE students choose a context (such as fairground rides) and then use the context to explore relevant physics in the style of a school textbook. Finally, throughout the course the students are required to keep a *learning log*, which they use to reflect on their personal subject knowledge development.

## **1.6 The Albion SKE course as a Community of Practice**

If the memorisation of physics content knowledge was considered sufficient to meet the requirements to enter a physics PGCE course, then it would be difficult to justify the resources required for a taught SKE course involving the attendance of students. Memorisation of factual physics knowledge could be achieved by students working alone, perhaps through a distance-learning course, or even studying from a textbook without any external support. Instead, the Albion SKE course is based around a group of students and tutors, working together to develop the students' practice of the subject of physics. Although students are assessed as individuals in terms of their success at achieving the course aims (rather than assessment of the group performance as an integrated unit), the course can be conceived of in terms of a *community of*

*practice* (Wenger, 1998). During the SKE course the elements of a community of practice are in evidence: there is *mutual engagement* (Wenger, 1998, p.73) and *joint enterprise* (p.77), as a result of the students' and tutors collectively focussing on a *shared repertoire* (p.82), in pursuit of the common goal of each individual progressing onto the PGCE course.

Of central importance in the idea of learning in a community of practice is the process of negotiating meaning. Meaning is negotiated during the "convergence" (p.55) of *participation* and *reification*. Wenger defined participation as

...the social experience of living in the world in terms of membership in social communities and active involvement in social enterprises (Wenger, 1998, p.55)

Participation is characterised by "the possibility of mutual recognition" (p.56), where during an interaction the participants can recognise aspects of themselves in others. Participation is a social act, even if it does not involve immediate interaction with others, or as Wenger puts it, participation "is not tantamount to collaboration" (p.56). For example, planning, alone at home, a school science lesson requires a teacher to consider the pupils and their needs, the setting the lesson will take place in, how the lesson should 'fit in' with the physics concepts covered during previous lessons, etc. It would be meaningless to plan a lesson with no knowledge or thought given to who the lesson is intended for.

Reification is 'making real' an idea. When we reify, we

...project our meanings into the world and then we perceive them as existing in the world, as having a reality of their own (Wenger, 1998, p.58)

For example, representing the idea of justice in the form of a universally recognised statue of a person holding a set of scales, or referring to the economy as 'reacting' to government announcements, as if these ideas are tangible entities that can be affected by events. In the context of physics subject knowledge, a formula is a result of reifying the relationship between a set of concepts into mathematical language that can then be written down, manipulated and discussed. For example, Newton's 2<sup>nd</sup> Law of Motion is a statement of how objects behave under

the influence of forces, that itself draws on subsidiary concepts such as *acceleration* or the idea of a *vector quantity*. This law can be reified mathematically into the formula  $F = ma$ . In lower secondary school this formula is talked about and used a great deal. One effect of this is that many learners, when asked to explain Newton's 2<sup>nd</sup> Law, will quote the formula  $F = ma$  in response. The formula has *become* Newton's 2<sup>nd</sup> Law in their minds and in their discourse. This can be convenient, but also carries with it the dangers of oversimplification and loss of insight into what the law is about. When learners proceed onto A-level physics, they then discover that Newton's 2<sup>nd</sup> Law is more generally a statement about the effects of forces, and the time over which they act, on the *momentum* of an object, leading to more sophisticated mathematical reifications. The  $F = ma$  reification is not incorrect, but it can now be seen as an application of the 2<sup>nd</sup> law in specific circumstances. This requires the pupils to re-reify Newton's 2<sup>nd</sup> Law.

The SKE course can be viewed as a site where student teachers are engaged in the processes of participation and reification as they strive to learn physics subject knowledge. The course is also a site of transition between different communities of practice which are all present during the course (see Fig. 2). When Nick, at the beginning of this chapter, says "I'm not a scientist, no way, because I'm a science *teacher*..." he is revealing a personal view of himself as a member of a community (science teachers) that is different from the community he sees himself as previously being a member of (science). The Albion SKE course represents an "active" community of practice (Wenger, 1998, p.228). There are "potential" communities (p.228) which students are trying to become members of, such as the community of practice of *physics* and of *physics teachers*. There are also "latent" communities of practice (p.228), such as the community of practice for the subject and course the students studied at university prior to joining the SKE course. Although they are no longer members of these communities, the students can still draw on their memories of them to inform how they negotiate meaning during the SKE course. It is possible to contest if there really is one community of practice of physics and one of physics teachers, but my general point remains that there are communities associated with each of these fields of practice that are distinct from the community of Albion SKE students. It is possible to continue to identify other

latent communities that may have a part to play in the SKE students' negotiation of meaning during the course, such as membership of the *A-level physics* community during their secondary schooling, etc. The students are participants in multiple nested communities of practice (for example, the community of practice of the Albion SKE course is nested within the community of practice of ITE courses generally). There are discontinuities between all these different communities based on the students' differing (or lack of) experience of participating in them. One way of looking at the SKE course is that it enables students to learn through crossing boundaries from their latent and active communities to also become members of potential communities. Wenger (1998) identifies two types of connections between communities: *boundary objects* and *brokering*. Boundary objects include "forms of reification" (p.105) which can help to make connections, such as documents, technical terms and physical artefacts. Brokering is done by people who can help to transfer and link aspects of practice from one community into another.

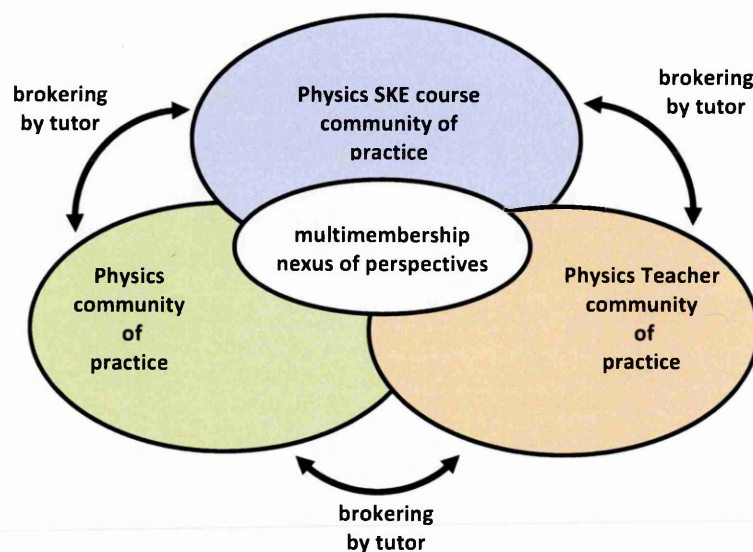


Fig. 2: Multiple communities of practice in the SKE course (adapted from Fig.4.1 in Wenger, 1998, p.105)

In the Albion SKE course the tutors are brokers who help the SKE students to move into the physics and physics teacher communities, and to make sense of the differing perspectives arising from multimembership. This brokering could manifest itself in a variety of ways. For example, the tutors could use teaching approaches designed to develop the SKE students' subject knowledge *and* knowledge of pedagogical approaches that could be useful when working with children.

During SKE sessions the tutors might explain ‘tips’ and pitfalls to avoid when helping children learn physics, and some of the common misconceptions that need to be addressed. The use of active learning activities in course sessions and the design of assessment tasks, such as developing a book chapter on an aspect of physics, are all examples of possible brokering by tutors, where practices from the community of physics teachers are brought into the practice of the community of Albion SKE students.

Wenger’s ideas about learning in communities of practice have been used widely to develop insights into the processes that influence learning in educational settings (for example, Adler et al., 2014; Korthagen, 2010; Murray et al., 2009; Harrison and McKeon, 2008; Ellis, 2007b; Benzie et al., 2005). I will use them in the specific setting of the Albion SKE course as a theoretical ‘lens’ through which to view my data as I develop answers to the research questions.

I have described the rationale for the research questions, the ITE context in which the research was conducted and how this context can be viewed conceptually as a community of practice. In the next chapter I examine the literature related to SKE courses and teacher subject knowledge development.

## **2. Subject knowledge enhancement: reviewing the literature**

Having identified in the preceding chapter the purpose and setting for this research, I will review the literature related to my research questions. First, in section 2.1, I will report the results of establishing during the early stages of the research the extent and nature of the field of literature related to SKE courses. I will show how my research relates to this field and addresses aspects of it that are under-researched. As my research proceeded, literature continued to be added to the field of work about SKE courses and I will include these later additions. SKE courses exist because of the perceived significance of the role of subject knowledge in the work of teachers. In section 2.2 I will focus on the literature about teacher subject knowledge. I will review a range of conceptualisations about the nature of teacher subject knowledge and how it develops, from individualistic-objectivist models to socially-constructed and situated models. Finally, in section 2.3, I will outline how ITE can be understood in terms of these subject models and how they can be related to each other.

### **2.1 Subject Knowledge Enhancement courses**

There have been many published articles about the processes and effectiveness of ITE (e.g. BERA, 2014; Dobber et al., 2012; Ellis, 2010; Korthagen et al., 2006; Brouwer and Korthagen, 2005; Byrnes et al., 2003); teachers' experiences of ITE and their journeys into teaching (e.g. Hillier et al., 2013; Koponen and Nousiainen, 2012; Chambers et al., 2010; Turner and Turner, 2000; de Jong and Brinkman, 1999); and the experiences and practices of teacher educators (e.g. Ellis et al., 2012; Lunenberg and Willemse, 2006; Cochran-Smith, 2005; Loughran and Berry, 2005). My initial search for literature about physics SKE courses showed that little had been published in this area, with Angell et al. (2005) and Mant (2010) being the only examples that reported any primary data about pre-PGCE physics subject knowledge development courses. Widening the search to include SKE-related courses in any subject uncovered Jones et al. (2008), which examines a chemistry SKE course, and several publications about Mathematics Enhancement Courses (MECs). I will report in

chronological order what has been published about pre-service physics courses and then how these compare with the published work about pre-service mathematics courses.

SKE courses evolved from the Physics Enhancement Programme (PEP), which was introduced in 2003 as a pilot programme by the Teacher Training Agency (a government agency since subsumed into the Dept. for Education). The PEP course is described by Ireson and Twidle (2004) as a route into physics teaching for those without a physics background. The course formed part of a two-strand approach to developing teacher subject knowledge, alongside the provision of “subject knowledge booster courses” (p.52) aimed at in-service teachers who need to teach sciences outside of their subject specialism. Ireson and Twidle (2004) do not evaluate either of these programmes; their intention being to inform school science teachers about the nature and purpose of these courses.

The first published research which included some examination of the effectiveness of the PEP course pilot was a paper by Angell et al. (2005) as a result of a presentation at the ESERA (European Science Education Research Association) Conference in Barcelona in 2005. This paper reports a three-year longitudinal study in England of the development of physics understanding by student physics teachers, compared to experienced in-service physics teachers. The participants were 41 students from three physics PGCE courses in England, 17 of whom had completed a PEP course, and 16 physics teachers who had at least three years of experience and were known for their good practice in the classroom. Questionnaires were used consisting of physics questions designed to “shed light on how respondents would express their content knowledge in a pedagogical context” (p.5). Each question included a diagram, such as various stages in the trajectory of a ball thrown into the air, along with a question or two about the physics of the situation shown. An example pupil response to the question(s) which reveals a misconception is shown, and the participants were asked to explain the physics and to comment on the pupils’ answers. The participants’ responses were “categorised and coded inductively” (p.5) along with quantitative analysis, using the Mann-Whitney U significance test. The authors propose a conceptual framework through which to understand the types of answers provided by



the participants, but for the purposes of my research, the main relevant finding was that no significant difference in subject knowledge, or pedagogical knowledge, could be determined between the student teachers with and without a PEP background. The experienced teachers showed greater pedagogical knowledge than the student teachers and the authors conclude that more attention should be given to creating “new ways and opportunities for the development of pedagogical thinking among novice teachers” (p.16). Angell et al. provides the first published evidence of the effectiveness of extended pre-service subject knowledge enhancement courses. However, it is not principally about PEP students, nor does it explore the student teachers’ experiences of the PEP course.

Shepherd (2008) presents an article about PEP courses that is similar in style and intention to Ireson and Twidle (2004), i.e. aimed at informing school science teachers about a course rather than presenting research that critiques it. Shepherd also summarises the Science Additional Specialism Programme (SASP), started in 2007 to support in-service science teachers to develop subject knowledge and pedagogical knowledge in their non-specialist science areas. Shepherd draws on Angell et al. (2005) to claim that the PEP course provides “a valid and important route into ITE” (Shepherd, 2008, p.45), but also states that more thought is needed about how to define success on PEP and SASP courses. He does not refer to additional research that might cast light on PEP course participants’ experiences or support his claim that PEP shows it is possible to bring non-specialists “up to speed” (p.48).

Campbell (2011) and de Winter (2011) both report on SASP courses, sharing details of how they work and participants’ experiences. Although both are about SASP (i.e. about a course aimed at in-service teachers rather than the pre-service teachers in my research) they both identify features of the course that could be relevant to my research. For example, both articles highlight the importance of course participants feeling that they have gained confidence in teaching physics, and that they value working together as a peer group. The articles report the need for subject knowledge development courses to consider an appropriate balance between developing understanding of physics and exploring pedagogical implications. Both articles present self-

reported post-course student evaluation data and there is no systematic data collection about the teachers' experiences.

At the same time as Shepherd (2008) published his article, Jones et al. (2008) published their evaluation of the Chemistry for Non-Specialists (CFNS) programme. CFNS was a three-year programme of courses based in Science Learning Centres and funded by the government, GlaxoSmithKline and the Royal Society of Chemistry. Its aim was to train 900 in-service biology and physics school teachers each year to teach chemistry to Key Stages 3 and 4 level. There were two phases to the evaluation. Phase 1 involved questionnaires completed by 184 CFNS participants. Phase 2 involved "case-study interviews" (Jones et al, 2008, p.i) with 28 CFNS teachers, 70 pupils and 10 school Heads of Science or CPD leaders. Although the Jones et al. report only concerns in-service teachers of chemistry, with passing mention of pre-service SKE courses, it is relevant to my research because it provides evidence of a wider policy context of government sponsored programmes to address the subject knowledge needs of non-specialist teachers of shortage subjects. The report takes a national-scale view of the CFNS course concept rather than focussing on any one particular course and its participants' experiences. There is also no exploration of how the course participants conceptualise subject knowledge.

The completion of the pilot phase of the PEP course led to the roll-out of SKE courses of various durations across ITE institutions in England from academic year 2008/9 onwards. Mant (2010) reports students' experiences of one particular course using data gathered via course evaluation questionnaires issued each term and at the end of the course. Brief case studies are presented of the academic and professional backgrounds of four students on the course, along with extracts of all students' questionnaire responses. The students' responses are described as "overwhelmingly positive" (p.7) about the course, with features such as developing awareness of links between what they are learning about physics and how to teach it valued highly by the students. In the same year, Chapman and MacBlain (2010) published their article which describes in detail the weekly learning activities during a particular chemistry SKE course. As with Campbell (2011) and de Winter (2011), the aim of Mant (2010) and Chapman and MacBlain (2010) is to inform teacher

educators about a particular course rather than to systematically collect and analyse data that can be used to develop critical insights into it.

The establishment of SKE courses as a normalised route towards QTS led to a perceived need within the science education community to clarify what is meant by the term *subject specialist*. The Science Community Representing Education (SCORE) (a collaboration of the Royal Society, the Institute of Physics, the Royal Society of Chemistry, the Society of Biology and the Association for Science Education) published a report intended to define *subject specialist*, and how such a definition can be used to inform appropriate targets for teacher recruitment and to monitor teacher retention in particular subjects (SCORE, 2011). SCORE proposes the term *subject specialist* should apply to teachers whose Bachelor degree is either in the subject to be taught, have relevant industrial experience or have completed a minimum 24-week SKE course. SCORE (2011) is significant in that the bodies involved in it recognise extended SKE courses as a legitimate route to producing subject specialist teachers with equal status to those who have a Bachelor degree background in the same specialism. The report strongly recommends that extended SKE courses be continued and funded by government in the future. Of particular relevance to my research is the concern expressed in SCORE (2011) that biology graduates may be choosing physics or chemistry SKE routes due to the enhanced funding and support available for them, instead of going straight into a biology PGCE course. The concern is that this may lead to possible deterioration in the quality of biology teachers in the future as well as concerns about the true motivation of such teachers to teach physics or chemistry. SCORE (2011) also calls for longitudinal research to assess if there is a correlation between student teachers' Bachelor degree subject backgrounds, their choice of teaching subject specialisation and the quality of their teaching. There is no mention in the report about the work by Hattie (2009) at attempting to synthesise what research has to say on the existence of such a correlation, although Hattie's analysis is not specifically about science teachers and ignores SKE courses.

The small number of articles published about pre-service subject knowledge development courses in physics (either PEP or SKE) have focussed on either describing the purpose of such a course,

advocating the approach taken on one particular course, or in the case of Angell et al. (2005), has focussed on analysing the students' subject knowledge. More has been published about mathematics SKE courses, which are known as MECs (Mathematics Enhancement Courses). Again, although these are not sited in the context of physics SKE courses, these articles about MECs place my research into a wider context.

May et al. (2008) present an evaluation of a MEC run by a consortium of universities in London, using mathematics academics and mathematics teacher educators. There is also one week of school-based time where students observe the workings of a school maths department. The research used a case-study approach, with data gathered during focus groups and individual interviews involving 18 participants, 3 of which were former MEC students on a PGCE course. The analysis approach is akin to grounded theory (although this term is not used) and consists of the assignment of codes to interview transcript data. These codes are then grouped into themes that cover the MEC students' views about the value of the course; their experience of it compared to their expectations; the effect of learning together as a group; and, the PGCE participants' views of their MEC experience. Students were positive about the MEC, with some minor criticisms about organisation and timetabling, and highlighted its value for "enabling students to experience a range of teaching methods" (p.153). May et al. conclude that the students valued "peer-assisted learning" (p.156) approaches and the insights into pedagogy they received from tutors during the course.

In the same year, Stevenson (2008) looked at a MEC run jointly by Hope and Edge Hill Universities. Stevenson's research reports early results of what is intended to be a larger-scale project that aims to evaluate the development of a MEC curriculum and its success at developing the students' subject knowledge, and to a lesser extent, students' pedagogical knowledge. She does this by using students' grades on entry and exit of the post-MEC PGCE course, compared to non-MEC students, to show that there is no significant difference between the two (although her judgement of significance is based on direct comparison rather than statistical analysis).

Exploration of the extent to which MEC students ‘understand mathematics in depth’, and how this influences their growing identities as mathematics teachers, is a theme of Adler et al. (2009), Hossain et al. (2013) and Adler et al. (2014). These articles use interviews to examine MEC students’ conceptualisations of mathematical knowledge and how they “construct themselves as be(com)ing mathematicians, teachers and/or mathematics teachers” (Hossain et al., 2013, p.40). The value of peer-teaching approaches and learning together as a group of peers are highlighted by Adler et al. (2014), who view the course through Lave and Wenger’s (1991) ideas of learning as apprenticeship. Two other small-scale studies of MEC courses are Stansfield (2012), who reports the effect of assessment feedback on MEC students’ beliefs about their progress, and Warburton (2013), who reports the early stages of a research project to explore if there is a correlation between degree class and final PGCE result for MEC and non-MEC students.

All of the publications above are small-scale in the sense that they present primary data collected in a small number of institutions. The first systematic attempt to look at pre-service SKE students’ experiences across a wide range of institutions, and across all subjects, appeared towards the end of my research. Gibson et al. (2013) reports the results of the third year of a three-year evaluation of SKE courses across England. Questionnaires were used to collect data about students’ achievement, background and experiences at four points during ITE: at the start and end of an SKE course, and then at the start and end of a PGCE course. Although some direct quotes from students’ qualitative responses to the questionnaires are included, the data are mostly presented in quantified form. The full report runs to 284 pages, but there are some key points from this report that are pertinent to my research:

- 25% of students identify barriers to engagement with their SKE subject that include limited formal teaching time and limited time in school (p.47)
- Although the first two years of Gibson et al.’s survey ignored pedagogical aspects, experience showed that, contrary to official guidance that SKE courses should focus on subject knowledge-only, most SKE courses do include consideration of pedagogy. Questions about pedagogical experience were then included, showing that 57% of students rated the

appropriate subject knowledge-pedagogy ratio as 80:20, 22% as 60:40 and only 10% as 100:0 (p.50), i.e. 90% of SKE students expect to learn about some aspects of pedagogy during their SKE course.

- 75% of SKE students think they have more teaching-relevant subject knowledge at the start of a PGCE course than a non-SKE PGCE student (p.54)

Although a rich source of data about SKE courses overall, Gibson et al. (2013) does not report in depth the stories of individual students or look closely at how SKE courses are taught: it provides a large-scale ‘birds eye’ view of the SKE landscape without zooming into any one particular SKE course.

As I have shown above, since SKE/PEP courses started running in some English universities, the conduct of SKE courses and the students’ experiences of engaging with physics for the purposes of preparing to teach it, are under-researched areas. What little that has been published in this area suggests that SKE students: value the collective experience of studying the course as part of a peer-group; want to study subject-specific pedagogical implications alongside the subject knowledge itself; and, perhaps see ‘success’ on their SKE course as achievement of a sense of confidence about utilizing their subject knowledge with learners.

## **2.2 Teacher subject knowledge**

The nature of teachers’ subject knowledge and its relationship to practice has been a focus for attention of researchers and policy-makers since the 1980s (e.g. Kind, 2013; Käpylä et al., 2009; Deng, 2007 and 2001; Lenton and Turner, 1999; Hashweh, 1996; Smith and Neale, 1989; Tamir, 1988), with recognition that there has been a relative lack of attention paid to it during ITE (Goodwin, 2003; Shulman, 1986). There is an “accepted wisdom” held by some within the education profession (Kind, 2009a, p.1531) that science teachers are more effective if they teach within their Bachelor degree subject specialism; the degree qualification acting as an indicator of having the necessary deep conceptual understanding to teach effectively. However, the evidence

to support this claim is lacking, with research instead suggesting that possession of a 'good' Bachelor degree is a less significant factor in a teacher's effectiveness at promoting pupils' learning than many policy-makers appear to expect (Hattie, 2009; Kind, 2009a). After conducting a meta-analysis of research studies on the relationship between a teacher's level of academic qualification in the subject and pupils' resultant learning outcomes, Hattie (2009) concluded that there is no statistically significant link. For Hattie, the following were significant in the practice of successful teachers: strong general academic ability; high quality relationships with pupils; ability to construct explanations based on the level of pupils' understanding; and a deep level of conceptual understanding of the key concepts of the subject and pupils' misconceptions about them. It is the published literature related to Hattie's last point that I will explore in this section. I will review the literature on teacher subject knowledge, identifying four examples of models that propose distinctive ways of conceptualising what is characteristic about teachers' knowledge and how it develops: Shulman (1986); Banks et al. (1999); Cochran et al. (1993); and, Ellis (2007a).

### ***The missing paradigm in educational research: content knowledge***

In most schools the curriculum is organised into school subjects, which correspond directly, at least in name, to the academic subjects studied by scholars (Stengel, 1997). Much of the literature about school teachers' subject knowledge takes the existence of these subjects as a given and then explores what teachers need to know about them in order to teach effectively. Most of the recent discourse about teachers' science subject knowledge development (e.g. Abell, 2008; Nilsson, 2008; Pardhan and Wheeler, 2000), and how it relates to knowledge of pupils' misconceptions, has been framed by Shulman's influential discussion of what he termed *content knowledge* as the "missing paradigm" in educational research (Shulman, 1986, p.8). During his early research on the medical diagnostic approaches used by doctors, Shulman noticed that doctors' skill in diagnosing medical conditions could not be explained entirely by the extent of their scholarly knowledge, but instead relied on understanding how to relate that scholarly knowledge to real cases presented by real patients. This experience informed Shulman's research

in education where he noted “that just knowing the content well was really important, just knowing general pedagogy was really important and yet when you added the two together, you didn’t get the teacher” (Berry et al., 2008, p.1274), and concluded that there exists a category of knowledge specific to teachers. Shulman divided content knowledge into three “categories” (Shulman, 1986, p.9):

- *Subject matter content knowledge (SMCK)* consists of the “amount and organization of knowledge per se in the mind of the teacher” (1986, p.9). This corresponds to the ‘facts’ of science and an understanding of how such knowledge has been generated. This is the primary domain of the scholar of science as well as the teacher.
- *Pedagogical content knowledge (PCK)* “goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching*” [original italics] (p.9) and is the area of knowledge distinctive to teachers. It includes knowledge of why some learners struggle to understand particular concepts and knowledge of representations and ways of explaining the subject effectively to others.
- *Curricular knowledge (CK)* includes knowledge of the programmes and routes that can be followed, and the resources that can be utilized, by a teacher. Shulman described it as “the pharmacopeia from which the teacher draws those tools of teaching that present or exemplify particular content and remediate or evaluate the adequacy of the student accomplishments” (p.10).

In creating his model of content knowledge, Shulman specified that a teacher’s subject matter content knowledge needs to consist not only of the factual knowledge of the subject, but also of the way such knowledge is structured and created by subject scholars, drawing on Schwab’s concepts of substantive and syntactic structures (Schwab, 1978). The substantive structures of a subject are the “conceptual devices which are used for defining, bounding, and analyzing the subject” (Schwab, 1978, p.246). For example, scientists might investigate a phenomenon differently if they have a wave model in mind as opposed to a particle model. The syntactic structures are the rules by which scholars decide if claimed new knowledge is valid or invalid, or



should be added to the accepted knowledge base. In science this would include knowledge of how scientists arrive at proposed new theories and how experiments are designed and interpreted to test a new theory. For Shulman, the source of a school subject is the academic discipline of that subject. The academic subject and the school subject are treated as “continuous” (Stengel, 1997, p.593), in that science teachers teach the same scientific ideas and facts as are used by science academics even though they may do so in a simplified form. The academic and school subjects are also different from each other, but related, with the academic subject preceding the school subject, i.e. science teachers draw on their knowledge of pedagogy, the curriculum context and the students to transform their knowledge of the academic subject into the subject matter of school science (Deng, 2007; Stengel, 1997; Shulman, 1987). There is a diverse range of views about the knowledge of the substantive and syntactic structures of science teachers should have and teach, with teachers’ syntactic knowledge of science in particular forming the object of much research in the guise of what is called knowledge of the nature of science. Some authors use the term Nature of Science (NoS) to signify the study of the epistemology of science that draws on contributions from various social studies subjects, such as philosophy, psychology, history and sociology (Abd-el-Khalick and Lederman, 2000; McComas et al., 1998; McComas and Olson, 1998), with the lack of one universal way of conceptualising science reflected in the insistence of Lederman et al. (2002) on using the term NoS and not *the* NoS. Despite differences in how school science curricula structure NoS, and place relative importance on its components (Gess-Newsome, 1999; McComas and Olson, 1998), there is a broad consensus about the aspects of NoS that science teachers should know about, such as scientific knowledge as: empirical in nature; involving theories and laws; requiring creativity and imagination; theory-laden; embedded in social cultures; derived through a commonly-accepted scientific method; and producing tentative knowledge that is open to change (Lederman et al., 2002; Abd-el-Khalick and Lederman, 2000). Examination of students’ and teachers’ NoS views reveals a range of understanding depending on depth of subject knowledge and prior learning experience, from ‘informed’ views about the above NoS aspects to ‘naïve’ views of science as the

objective activity of the creation of knowledge without the influence of preconceived theories or cultural influences (Faikhamta, 2013; Lederman et al., 2002; Abd-el-Khalick and Lederman, 2000).

Shulman's conceptualisation of PCK as a distinct body of knowledge has provided a theoretical lens through which some researchers have explored teacher subject knowledge (e.g. Burn et al., 2007; Loughran et al., 2004; de Jong, 2000; Fernández-Balboa and Stiehl, 1995), with development of PCK regarded by some as in most need of attention during ITE courses (e.g. Halim and Meerah, 2002; Preece, 1997). The evidence for the existence of PCK as a discrete body of knowledge is unclear from Shulman's work. Some authors characterise PCK as arising when "content and pedagogy are *blended*" [my italics] (Kind, 2009b, p.173), while others describe PCK as derived by *transforming* SMCK (e.g. Lock et al., 2011; Halim and Meerah, 2002; de Jong, 2000; van Driel et al., 1998). There is considerable variation in how the term PCK is conceptualised by others.

Tamir (1988) extends Shulman's idea of PCK to consist of knowledge and skills (in an attempt to distinguish between propositional and procedural knowledge) in the four categories of students, curriculum, instruction and evaluation (i.e. assessment). Here Tamir is including in his "subject matter specific pedagogical knowledge" (p.100) some of the elements of Shulman's curricular knowledge (Shulman, 1987 and 1986). Grossman (1990) conceptualised PCK as consisting of four components: knowledge of the curriculum, knowledge of instructional approaches; knowledge of students' subject understanding; and, conceptions and beliefs about the purposes for teaching the subject. Shulman's idea of curricular knowledge (1987 and 1986) is also included by Grossman within a wider view of PCK, which requires consideration of a teacher's beliefs about teaching. Magnusson et al. (1999) developed Grossman's ideas further by defining PCK in terms of five components (p.97):

- a) Orientations toward science teaching
- b) Knowledge and beliefs about science curriculum
- c) Knowledge and beliefs about students' understanding of specific science topics
- d) Knowledge and beliefs about assessment in science

e) Knowledge and beliefs about instructional strategies for teaching science

They define orientations towards teaching as “teachers’ knowledge and beliefs about the purposes and goals for teaching science at a particular grade level” (p.97). Orientations take into account teachers’ goals for teaching science and the consequent characteristics of how they go about that teaching (see Fig. 3):

Orientation	Goal of teaching science
Process	Help students develop science process skills
Academic rigor	Represent a particular body of knowledge
Didactic	Transmit the facts of science
Conceptual change	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naïve conceptions
Activity-driven	Have students be active with materials and ‘hands-on’ experiences
Discovery	Provide opportunities for students on their own to discover targeted science concepts
Project-based science	Involve students in investigating solutions to authentic problems
Inquiry	Represent science as inquiry
Guided inquiry	Constitute a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science

Fig. 3: The goals of different orientations to teaching science (Table 1 from Magnusson et al., 1999, p.100)

For example, a teacher with an *activity-driven* orientation might design some practical work that requires children to test the law of reflection, whereas a teacher with a *discovery* orientation might design practical work so that the children could discover the law for themselves. Both teachers might use exactly the same practical equipment, but the purpose of each lesson will be different, which is what reveals the teachers’ distinct orientations. Other authors place more emphasis on teachers’ orientations being represented by their “general patterns of thought and behaviour” (Anderson and Smith, 1987, p.99), i.e. it is how they are observed to act that reveals their orientations as much as what they claim their purposes are. Orientations to teaching are not a primary focus of this research on the Albion SKE course, although I draw attention to them here because they inform how some authors define pedagogical knowledge.

In a review of the literature on PCK, van Driel et al. (1998) summarise the variety of categories of teacher knowledge that are included under the umbrella of PCK by various authors (Fig. 4).

Table 1  
Knowledge components in different conceptualizations of pedagogical content knowledge

Scholars	Knowledge of:						
	Subject matter	Representations and Strategies	Student Learning and Conceptions	General Pedagogy	Curriculum and Media	Context	Purposes
Shulman (1987)	<sup>a</sup>	PCK	PCK	<sup>a</sup>	<sup>a</sup>	<sup>a</sup>	<sup>a</sup>
Grossman (1990)	<sup>a</sup>	PCK	PCK	<sup>a</sup>	PCK	<sup>a</sup>	PCK
Marks (1990)	PCK	PCK	PCK	<sup>b</sup>	PCK	<sup>b</sup>	<sup>b</sup>
Cochran, et al. (1993)	PCK <sup>g</sup>	<sup>b</sup>	PCK <sup>g</sup>	PCK <sup>g</sup>	<sup>b</sup>	PCK <sup>g</sup>	<sup>b</sup>
Fernández-Balboa & Stiehl (1995)	PCK	PCK	PCK	<sup>b</sup>	<sup>b</sup>	PCK	PCK

<sup>a</sup>Distinct category in the knowledge base for teaching.  
<sup>b</sup>Not discussed explicitly.

Fig. 4: “Table 1” from van Driel et al. (1998, p.676)

Some authors include *subject matter* knowledge (Shulman’s SMCK) within PCK while others include knowledge of curriculum materials (Shulman’s CK). Despite the variation in definition, all the reviewed authors agree that two essential ingredients of PCK are knowledge of learners’ misconceptions and knowledge of effective representations of subject matter.

Van Driel et al. (1998) proposed that PCK is developed through an

integrative process rooted in classroom practice, implying that prospective or beginning teachers usually have little or no PCK at their disposal (p.677)

They do not appear to have considered the possibility that the embryonic classroom practice of novices might instead develop *from* a body of pre-existing PCK that they already have. The view that novice teachers have no PCK is reminiscent of a *tabula rasa* view of learning and is echoed in the work of others. For example, Van der Valk and Broekman (1999), in their analysis of student teachers’ early lesson plans, claim that as those lessons had been planned before the student teachers had gained school-based experience, the students “did not possess any PCK” (1999, p.15). Frederik et al. (1999) offer a similar view when they claim that student teachers need to make a shift from a theoretical perspective to a teacher perspective. As they are new teachers, this shift has not taken place yet so “one cannot speak of PCK” (1999, p.62).

Shulman highlighted the importance of good subject knowledge for effective pedagogy, with a weak subject understanding leading to inflexible and didactic pedagogical approaches (Berry et al., 2008). However, Shulman (1987 and 1986) implied a view of subject knowledge as an entity that is objective and resides with, and is therefore developed by, individuals. His model pays no attention to the context in which teaching is taking place or to teaching as an interaction between teacher and learners (Grossman and McDonald, 2008; Sockett, 1987). This objectivist view is contested by those who question Shulman's distinction between SMCK and PCK. Shulman himself appears to have acknowledged this as a limitation in his model by recognising that it "employed constructs that were strictly cognitive and individual" (Shulman and Shulman, 2004, p.258). Several authors express disquiet about the "elusive nature" (Kind, 2009b, p.170) of how PCK is conceptualised and the apparent lack of any substantive examples of PCK that can be pointed to and studied by student teachers (Settlage, 2013; Berry et al., 2008; Bucat, 2005).

### ***School knowledge vs. subject knowledge***

Banks et al. (1999) (reproduced as a journal article in Banks et al., 2005) criticise Shulman's view of subject knowledge as "a static body of content somehow lodged in the mind of the teacher" (Banks et al., 1999, p.91). They propose that teachers' subject knowledge is created through "*didactic transposition*" (p.92):

...a process of change, alteration and restructuring which the subject matter must undergo if it is to become teachable and accessible to novices or children (p.93)

What is distinctive about this 'school knowledge', following 'transposition', is that it has become linear, re-formed and sequenced in an orderly way. This is in contrast to the messiness and non-linearity of the scholarly knowledge it is derived from, and how people actually develop personally constructed meanings. In my own subject of science, it has long been recognised that the neat and tidy picture presented in school science of scientific ideas progressing in a linear fashion from hypothesis to experiment to conclusions, often bears little relation to the reality of how scientists

actually *do* science (Hodson, 2014 and 1998; Kuhn, 1996; Duschl, 1990). The model Banks et al. (1999) develop consists of three areas of knowledge: *subject knowledge*, *school knowledge* and *pedagogic knowledge* (see Fig. 5).

Banks et al.’s (1999) *subject knowledge* corresponds to Shulman’s SMCK. Their view is that *school knowledge* is the result of didactic transposition of subject knowledge and also includes Shulman’s curricular knowledge. *Pedagogic knowledge* includes knowledge of teaching and learning, although this alone is insufficient unless “integrated into an understanding of the crucial relationship between subject knowledge and school knowledge” (p.95). These three areas are not static and separate, but interact dynamically along with the *personal subject constructs* of the teacher, deriving from the teacher’s prior experiences and beliefs, and knowledge of teaching.

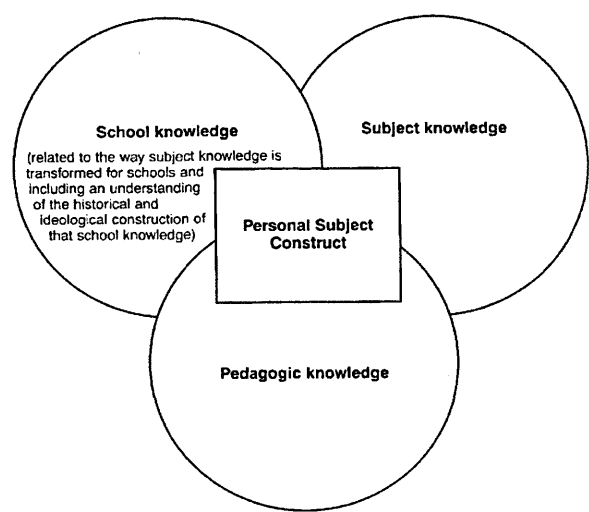


Fig. 5: “Teachers’ professional knowledge” (Fig.7.1 from Banks et al., 1999, p.94)

The Banks et al. model of teacher knowledge appears to be similar to Shulman’s construct in two key aspects. First of all, the model emphasises the *individual* teacher’s experience and construction of subject knowledge, which is independent of the context in which she or he operates. Secondly, the subject knowledge needed in the school setting is portrayed as sufficiently different from the non-educational setting as to merit its own category. *Subject knowledge* appears to be the domain of the ‘academic’ practitioner of that subject (e.g. the domain of the research scientist), while *school knowledge* is the domain particular to the teacher

of that subject. As with Shulman (1986), for Banks et al. (1999) the school subject of science is derived from the academic discipline of science through a process of transformation (Deng, 2007; Stengel, 1997). Although Banks et al. prefer the term 'transposition' there does not appear to be any significant distinction from how Shulman and others use 'transformation' to signify the derivation of school knowledge from an established disciplinary knowledge (Ellis, 2007b). Where Banks et al. differ from Shulman (1986) is in their emphasis on teachers' professional knowledge resulting from the interaction between the three types of knowledge in Fig. 5, although there is no suggestion of interaction with the eventual child learners having a place in this model. The Banks et al. model appears to be useful in supporting teachers in different settings to conceptualise their subject knowledge for the purposes of professional development (e.g. Banks, 2008; Banks et al., 2004), although no evidence is presented to support the distinction between school knowledge and subject knowledge. It also presents teacher-specific subject knowledge (*school knowledge*) as a body of context-independent knowledge in its own right that is static and 'owned' solely by the teacher.

### ***Subject knowledge and pedagogic knowledge: an unhelpful distinction***

The division of subject knowledge into discrete 'scholarly' and 'teacher-specific' forms is criticised by some for suggesting that subject knowledge is objective (Cochran et al., 1993; McEwan and Bull, 1991; McNamara, 1991, McEwan, 1989) and can be learned on an individual and context-free basis (Ellis, 2007a and 2007b; Shulman and Shulman, 2004). Some authors, such as Cochran et al. (1993) and McEwan and Bull (1991), argue that such a view does not account for the development of subject understanding through experience of working with learners. McEwan and Bull (1991) argue against the existence of a teacher-specific body of knowledge, such as PCK, and instead argue that all knowledge has a pedagogic basis (Segall, 2004). To have "deep understanding" (Biggs and Tang, 1999, p.20) of a concept is to be able to formulate it using language and doing so is an act of communication. Communicating to others requires selection of appropriate language, analogies and structure, which will depend on the context as

“[e]xplanations are not only *of* something; they are also always *for* someone” [original italics] (McEwan and Bull, 1991, p.332). This is a pedagogical act that scholars engage in, and is not the exclusive preserve of teachers, because:

[s]cholars must be concerned with the comprehensibility and teachability of their assertions, that is, with whether those ‘representations’ can find a meaningful place in others’ webs of belief...the justification of scholarly knowledge is inherently a pedagogical task (McEwan and Bull, 1991, p.324).

This is a claim about subject knowledge that moves away from body-of-knowledge ideas (e.g. Banks et al., 1999; Grossman, 1990; Shulman, 1986) and towards a subject-knowledge-as-process model (e.g. Ellis, 2007a; Cochran et al., 1993). For example, Cochran et al. (1993) re-conceptualise PCK as *pedagogical content knowing* (PCKg), to reflect the socially-situated nature of teachers’ constructed explanations. PCKg is what distinguishes the “expertise of teaching” (p.267) from scholarly knowledge of subject matter, and arises from the integration of understanding of four components of pedagogy (Fig. 6), illustrated by the shaded overlapping areas.

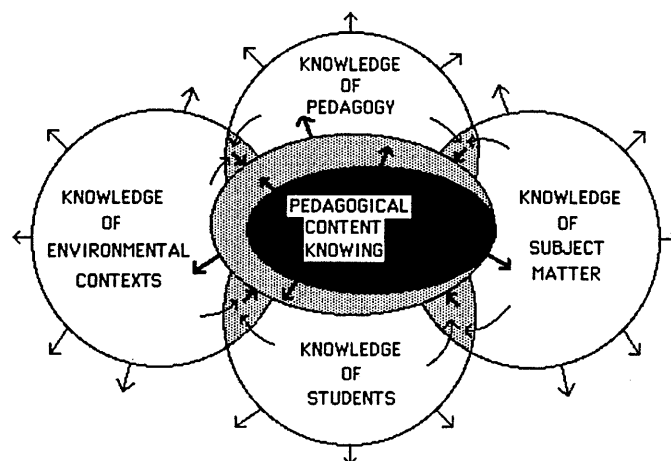


Fig. 6: “A Developmental Model of Pedagogical Content Knowing (PCKg)” (Fig.1 from Cochran et al., 1993, p.268)

PCKg is a product of integrating knowledge of: the students; of pedagogy; of subject matter; and of the environmental context of learning. The arrows (Fig. 6) signify that these areas are all expanding and integrating during a teacher’s development, resulting in:



conceptual change and conceptual integration to the point that the resulting PCKg...is distinctly and qualitatively different from the types of understanding from which it was constructed (Cochran et al., 1993, p.267)

Cochran et al. (1993) propose that one consequence of the idea of PCKg for ITE programmes is that student teachers' learning should be in contexts as close as possible to the situations in which they will be applying their knowledge, so that they have "repeated experiences that deliberately promote simultaneous learning of the components" (p.270).

Ellis (2007a and 2007b) proposes that subject knowledge should be treated as "complex, dynamic and as situated as other categories of teachers' professional knowledge" (Ellis, 2007a, p.447) and defines it broadly as "a teacher's knowledge that is directly related to school subjects and the curriculum" (Ellis, 2007b, p.60). He argues that discourse about subject knowledge has been dominated by a perspective of "autonomous professionalism" (Ellis, 2007a, p.448), where subject knowledge that exists outside of the realm of education (the objective subject knowledge of the scholar) is transformed, transposed or converted for use in educational settings (the specialist 'craft'-dominated knowledge of the teacher). Ellis claims this conceptualisation is characterised by three epistemological problems (pp.449-451):

- *the problem of dualism* (scholarly subject knowledge is presented as context-free compared to the situated subject knowledge of teachers)
- *the problem of objectivism* (subject knowledge as objective so that it can be 'delivered' to teachers and 'boosted' or 'topped up' by context-independent courses)
- *the problem of individualism* (subject knowledge is something that resides entirely with individuals, is intra-personal and can therefore be 'audited' by written tests)

Ellis draws attention to the importance of teaching and subject knowledge development taking place in the context of a community of practice (Wenger, 1998; Lave and Wenger, 1991). He represents his model diagrammatically for the specific subject of English. I have adapted Ellis's diagram (Fig. 7) to illustrate how his model applies to subject knowledge for teaching physics.

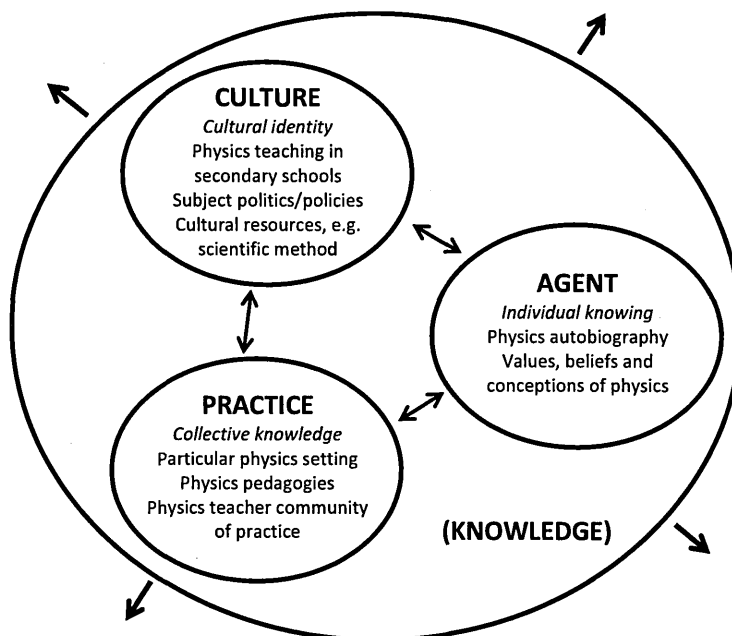


Fig. 7: The dynamic social systems within which physics teachers' subject knowledge is accessed and developed (adapted from Fig.2 in Ellis, 2007a, p.456)

Ellis envisages a dynamic model of subject knowledge development as the outcome of interactions between three social systems or “dimensions” (Ellis, 2007a, p.455):

*Culture* – the arena for practice that “determines the boundaries of the field and the rules by which the field as a whole validates knowledge” (p.456). Teachers develop their subject knowledge partly through legitimate peripheral participation in the culture of science teachers (Lave and Wenger, 1991). Resources used in the practice of science teachers also have a cultural value or significance; both physical resources (e.g. the Bunsen burner) and intellectual resources (e.g. the particular view of ‘scientific method’ espoused through GCSE coursework).

*Practice* – teachers are members of a community of practice, which develops a form of “collective knowledge” about their subject, such as subject-specific pedagogies, and “suggests the potential by which individual knowing can be validated as knowledge” (Ellis, 2007a, p.457).

*Agent* – the individual student teachers and the conceptions and prior experiences they bring to their participation in the community of practice of teachers.

Ellis (2007a) focusses on how the subject knowledge for a particular context develops dynamically according to the demands of that context and the interactions of the individuals (teachers and learners) within it. As with Cochran et al. (1993), the arrows (Fig. 7) signify that the field of subject knowledge itself is expanding, as the community of subject scholars modify what is accepted as knowledge, and the community of teachers reinterpret what is included in the curriculum. For Ellis, teachers' subject knowledge is "a form of collective knowledge" (p.458), where what is counted as subject knowledge, and how it is represented to children, is negotiated between teachers as a body of practice. Student teachers do not have a static body of pedagogical content knowledge to 'study'. Instead, they are inducted into a set of pedagogical practices. One note of caution about Ellis (2007a) is that the research from which he derives his model was conducted exclusively with student teachers of English. I suggest that the nature, or even existence, of a body of subject knowledge that is English is perhaps more contested than is the case for science, where there is a body of knowledge and practices that are associated with a scientific community. Nevertheless, Ellis claims that his model is applicable to all school subjects. His ideas are further developed in depth in Ellis (2007b), where he proposes a social model of subject knowledge learning that draws on the idea of knowledge development within a community of practice through processes such as *negotiation of meaning* (Wenger, 1998).

### **2.3 Relating subject knowledge models and initial teacher education**

In section 2.2, I discussed a variety of attempts in the literature to represent what is distinctive about the subject knowledge of teachers, and how it develops, compared to the subject knowledge of 'scholars'; a distinctiveness that is couched by many in terms of a subject-specific pedagogical knowledge (Kind, 2009b). I focussed on four models in particular, which have either helped to shape the discourse about teacher knowledge or represent different ways of conceiving it: Shulman (1986); Banks et al. (1999); Cochran et al. (1993); and, Ellis (2007a). When the SKE-

followed-by-PGCE ITE route is interpreted in the light of these models, it is possible to identify when each aspect is intended to be addressed (see Fig. 8).

	SKE course	PGCE course
Shulman (1986)	Subject Matter Content Knowledge (SMCK)	Pedagogical Content Knowledge (PCK) Curricular Knowledge (CK)
Banks et al. (1999)	Subject knowledge	School knowledge Pedagogic knowledge Personal Subject Construct
Cochran et al. (1993)	Knowledge of Subject matter	Knowledge of Pedagogy Knowledge of Students Knowledge of Environmental Contexts Pedagogical Content Knowing (PCKg)
Ellis (2007a and 2007b)	Subject knowledge	Subject knowledge

Fig. 8: Content of SKE and PGCE courses in terms of subject knowledge models

As discussed in chapter 1, the PGCE course assumes that students’ possession of a relevant Bachelor degree provides them with sufficient knowledge of the subject to enable the course to focus on developing knowledge of how to teach it in school. What is immediately apparent in Fig. 8 is the diverse range of conceptualisations of what students on the PGCE course should be developing, depending on which model is used to inform its design. Also, the broad definition of ‘subject knowledge’ used by Ellis (“a teacher’s knowledge that is directly related to school subjects and the curriculum” (2007b, p.60)) does not facilitate a meaningful distinction between the content of the SKE and PGCE courses: his model describes a way of conceptualising how teachers develop subject knowledge, which would be enacted differently during the SKE and PGCE courses, rather than different ‘types’ of knowledge. Looking specifically at the SKE course, Ellis (2007a) and Cochran et al. (1993) say more about the processes required for student teachers to develop their subject knowledge, and especially knowledge of subject-specific pedagogy, than either Shulman (1986) or Banks et al. (1999). I propose that these four models can be placed on a continuous spectrum of underlying epistemological views of how teachers’ develop subject-specific knowledge for teaching (see Fig. 9).

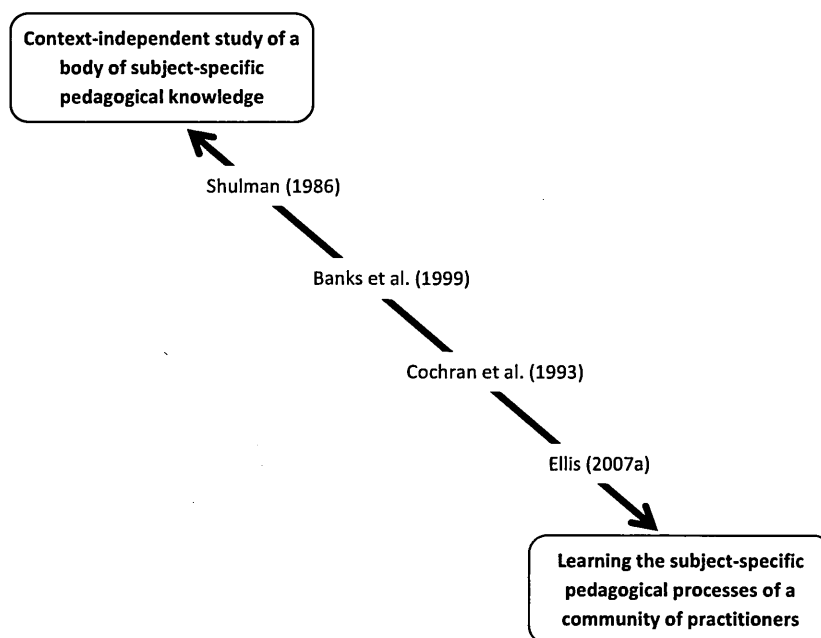


Fig. 9: A spectrum of epistemological views underlying models of teacher subject knowledge growth

At one end of the spectrum are epistemological perspectives of a teacher's subject knowledge development as a context-independent affair, as she or he studies content knowledge and content-specific pedagogical knowledge. For example, Shulman (1986) lies closer to this end of the spectrum than Banks et al. (1999). Both models are predicated on the existence of an objective body of teacher knowledge (*PCK* in the case of Shulman and *school knowledge* in the case of Banks et al.). Although different authors use the term *PCK* to encompass a variety of aspects of teachers' professional knowledge, all conceive of *PCK* as a body of knowledge that is derived from the relevant body of scholarly knowledge (Deng, 2007; Segall, 2004). Although Shulman himself referred to *PCK* as arising from the blending of content knowledge and pedagogy (Shulman, 1986), it is clear that the production and subsequent learning of content knowledge comes first and it is then the role of the teacher to generate *PCK* from this predefined body of content (Segall, 2004). The discourse around *PCK* is frequently suggestive of *PCK* acquisition as taking place through pre-service study by student teachers, which can be accomplished without direct contact with school students. Banks et al. (1999) draw attention to the need for teachers to develop a school-specific version of scholarly subject knowledge, and it is this knowledge, rather

than disciplinary knowledge, that they need to learn to teach. Their picture is perhaps more faithful to what is actually taught in school, given that the way physics is constructed and experienced by children is different from the way it is experienced and practised by physicists: school physics is constructed by teachers so that the sequence in which concepts are encountered is designed to facilitate children to learn it, rather than to represent how a physicist might view their subject or engage with it to develop new knowledge (Deng, 2007). However, Banks et al. (1999) still suggest teacher knowledge development is carried out on an individual basis, with no expectation that interaction with real learners will play a part in its construction. At the other end of the spectrum are constructivist perspectives of a teacher's subject knowledge growth as learning the subject-specific pedagogical processes of a community of practitioners. Cochran et al. (1993) introduce the notion of *pedagogical content knowing* to signify this, while Ellis (2007a) emphasises that a teacher learns subject knowledge through engaging with the socially-situated practices of a community of science teachers. Both models emphasise that subject knowledge development is contingent on interacting with learners. They also question the distinction made at the Shulman/Banks end of the spectrum between separate bodies of content knowledge and pedagogical knowledge. Instead they draw on the idea that scholarly knowledge has a "pedagogical dimension" (McEwan and Bull, 1991, p.318) so that learning subject knowledge cannot be separated from learning about how it communicates meaning (Segall, 2004; McEwan and Bull, 1991 and 1989).

Placing these models on a continuous spectrum raises questions about how 'continuous' it really is and whether using such a linear axis means that this is the only useful way of distinguishing between the models. My intention is to indicate qualitatively that the models can be ordered along an axis of epistemological views and not to indicate a quantitative position for them on an absolute scale.

In chapter 6 I will revisit these subject knowledge models and consider which correspond most closely with the participants' experiences during the Albion SKE course.

### 3. Research Design

In this chapter the research design will be explained and justified. I will start by discussing my epistemological and methodological stances (section 3.1), and how they informed the choice of data collection methods used (section 3.2). I will then explain the approach taken to data analysis (section 3.3) and comment on factors affecting reliability and validity (section 3.4).

#### 3.1 Methodological stance

My research questions were developed with an exploratory approach in mind rather than the testing of a hypothesis. The questions assumed that the students not only had experiences that were unique to them, but that their experiences shaped the beliefs, values and mental models I was interested in exploring. I adopted an epistemological view described as *interpretivism* (Gray, 2014; Crotty, 1998; Miles and Huberman, 1994), *naturalistic* (Cohen et al., 2011) or *social constructivist* (Creswell, 2009). The interpretivist researcher may hold an objectivist ontological view, but now regards the people who are being researched as participants in the construction of their own interpretations of the physical and social worlds, based on their situated experience of them. The goal of interpretivist research is to explore the participants' worldview and how they create their interpretations. Often, qualitative data (data that is expressed in written or spoken words, or in pictorial form) are used with a view to developing explanations which are situated in a particular social setting, rather than to test hypotheses. There may be no attempt to draw general conclusions or to formulate an over-arching theory; in fact, producing these is seen by many as intrinsically impossible due to the socially-situated nature of social knowledge (Schofield, 1989). Instead, deep insights are sought into the specific situations examined, perhaps over a prolonged period of time, with the aim to develop understanding. This stance requires recognition by the researchers that they too interpret their world and construct meanings.

This research is not examining all SKE courses in general, but is sited in one particular SKE course as enacted in one institution. As such, this research could be conceived of as a case study, in the sense of “research on a system bounded in space and time and embedded in a particular physical and sociocultural context” (Gobo, 2011, p.16). Although there is a diverse range of views in the literature about its precise definition (Gray, 2014; Gobo, 2011; Bassey, 1999), there is consensus that case study research requires in-depth study of a phenomenon in context using a variety of data collection methods and sources, with the aim of producing a definitive account of the researched case (Lewis and Nicholls, 2014; Stark and Torrance, 2005). However, the aim of my research is not to produce an in-depth account of the Albion SKE course as ‘the case’, but to research the participants as examples of students who happen to be on this particular SKE course. I suggest that my data are not rich enough to lead to a meaningful case study of this particular SKE course and I have therefore chosen not to define the research in this way.

An additional methodological aspect to be considered is my positionality. As originally conceived, this research was ‘insider research’ (Gray, 2014; Plowright, 2011; Sikes and Potts, 2008) as I adopted a dual identity of tutor and researcher. I had been involved in co-developing the SKE course from its inception and wanted to learn more about the students’ experiences in order to improve my practice, and the future design of the course. As an insider-researcher I had to be alert to possible tension for the participants, as they negotiated a revised relationship with me as tutor-researcher, and be aware of possible bias, as I perhaps unconsciously looked for validation of aspects of the course I had invested time in as a tutor. However, my position as an insider enabled unique understanding of the research setting and insights into the participants’ experiences that an outsider researcher would not have. Despite this, I was at times uneasy with how my status as course tutor might influence my participants’ responses. This unease was resolved when I left Albion University in October 2012, during the data collection phase. I then became an ‘outsider-researcher-with-former-insider-knowledge’. The disadvantage of this move was that some of the impetus for this research (informing my practice on the SKE course) had been removed. The advantage was that I could still bring my inside knowledge of the SKE course



to the research without the constraints of the possibly-conflicting demands of being a course tutor.

3.2 Data collection design and methods

I collected data from two successive cohorts of SKE students and continued to collect data from participants from the first cohort as they progressed through the subsequent PGCE course. Data collection took place using individual semi-structured interviews and focus groups (see Fig. 10) for an overview of the data collection schedule).

Participant (pseudonyms)	Oct 2011	Feb 2012	Sept 2012	March 2013	May-July 2013
Cohort 1	2011/12 SKE course		2012/13 PGCE course		
	Ind. Interview 1	Ind. Interview 2	Ind. Interview 3	Focus Group	Ind. Interview 4
Ben	✓	✓	✓	✓	✓
Nick	✓	✓	✓		✓
Andy	✓	✓	✓		✓
David	✓	✓	✓	x	✓
Sally	✓	✓	✓	Broke off contact	
Tom	✓	✓	Withdrew from participation		
Cohort 2			2012/13 SKE course		
			Ind. Interview 1	Focus Group	Ind. Interview 2
Charlie			✓	✓	✓
Jen			✓		✓
Daniel			✓		✓

Fig. 10: Data collection schedule

Six students from the 2011/12 SKE course cohort of twelve volunteered to participate. One of those students (Tom) withdrew from the research at the start of the PGCE year (citing concerns about the anticipated workload of the PGCE course) and another (Sally) broke off contact soon after starting the PGCE course. I decided to withdraw both students’ incomplete data from use in this thesis (apart from use of a small segment of Sally’s data to illustrate a point about

mistranscription in Appendix F). Three students from the 2012/13 SKE course of nine volunteered to participate. I was a course tutor for cohort 1 throughout their SKE course, but not for their PGCE course. I taught the first two SKE course sessions for cohort 2 before leaving Albion University. Pseudonyms were allocated to all participants and it is these names that will be used throughout this report.

A range of data collection methods was considered and two methods were selected that would enable the participants' stories to be heard: individual interviews and focus groups. Their selection and implementation are discussed below. Other approaches to data collection were considered and rejected, as they would have either not yielded data of sufficient quality to answer the research questions or were not practical for ethical reasons. For example, questionnaires were not used because the intention of the research was to explore participants' views in depth during an interaction with them (such as during an interview). Analysis of the students' learning logs was not possible on ethical grounds, as the students had not been consulted at the beginning of their SKE course on the possibility of the logs (and any of the other course assessment materials) being used as research data.

### **3.2.1 Individual interviews**

Answering the research questions required me to develop insights into the participants' conceptualisations in a way that would be less easily and quickly achieved through observational approaches. I decided to use semi-structured individual interviews (Barbour and Schostak, 2005; Arksey and Knight, 1999) as my primary approach to data collection. I saw the purpose of the interviews as 'constructing a story' rather than 'uncovering truths', what Kvale and Brinkmann (2009) describe as interviewer as "traveller" (telling a story as a result of journey) compared to interviewer as "miner" (uncovering buried knowledge) (p.48). I approached the interviews as "professional conversations" (Kvale and Brinkmann, 2009, p.2; Charmaz, 2006, p.25) where pre-planned questions were used to guide exploratory discussion with each participant, rather than a

rigid question-and-response interrogation. Such an approach enabled me to be flexible with the order of questions and allowed follow-up of potentially useful avenues of exploration depending on what each participant brought to the discussion. However, I am mindful of claiming too much about the extent to which all of the interviews were truly conversations, in the sense of a dialogue between interested equals, given the power asymmetry between researcher-tutor and participant-student.

Interview questions were designed by first identifying “researcher questions” (see Appendix B), which are the “project’s thematic research questions...usually formulated in a theoretical language” (Kvale and Brinkmann, 2009, p.132) and are derived from the research questions. The researcher questions were then translated into ‘what’ and ‘how’ questions to encourage the participants to give descriptive answers, rather than ‘why’ questions which might lead too quickly into the participants trying to justify and over-analyse their responses (p.133). Answers to research questions 1 and 3 could be sought through collecting data at one point in the participants’ SKE course experience. Although this might yield useful insights, I decided at an early stage that deeper insights could be developed through taking a longitudinal approach and gathering data more than once during the SKE course (and PGCE course for cohort 1). Each interview consisted of broadly the same questions (see Appendix B) so that I could examine changes in how the participants’ described their experiences and conceptualisations.

During each interview I asked the students to draw a diagram that represented their understanding of what is covered by the term ‘physics subject knowledge’. I spent part of each interview asking the participants to explain some of the features on their diagram. The diagrams helped to make explicit the students’ implicit assumptions about what they needed to learn during the SKE course, and they expanded the richness of the interview data by reducing the reliance on verbal-only interaction. The centre of attention during the interview would then be the diagram, as an artefact the participants and I could discuss together, which would also reduce some of the pressure the participants might feel about being interviewed by their tutor. Ellis (2007b) used a similar approach and justified his use of student-drawn diagrams as a way of

exploring his research questions in a “multi-faceted way” (p.68). During the first round of data collection I intended for the diagrams to function primarily as a structuring device for the conduct of the interviews, but as the interviews progressed I decided that the diagrams were potentially rich data in themselves. As with Ellis (2007b) I was wary of drawing too many conclusions about what the diagrams revealed about the sophistication of the participants’ thinking. This was important given the deliberate lack of prior notice to the participants that they would be drawing these diagrams and the lack of thinking time available for their construction. However, unlike Ellis, I did not plan to conduct a quantitative analysis of their structural features.

All interviews lasted between 45 and 70 minutes; were audio recorded; and were conducted at Albion University (with the exception of interview 2 with Jen, which was conducted by telephone as she had returned home to Ireland). I transcribed the recordings myself for the first eight interviews and then used a transcription service for the remainder. I decided at an early stage not to transcribe many non-verbal responses and verbal tics as I planned to engage in content analysis (Gray, 2014; Cohen et al., 2011) rather than conversational or discourse analysis (Heritage, 2011; Kvale and Brinkmann, 2009). All transcripts were checked and edited prior to analysis by repeated re-listening to the entire audio recording. This re-listening was invaluable for two reasons. First, it enabled me to take note of points of potential interest that I was unaware of during the interviews themselves. Second, the transcription process itself is an act of interpretation (Kvale and Brinkmann, 2009; Arksey and Knight, 1999). During the re-listening and editing process I discovered several examples where a participant’s response had been mistranscribed; many of them were simple typos, while some had a significant effect on how a response could be interpreted. Appendix F includes one example that illustrates how alternative punctuation of a transcribed response altered my interpretation of it. An example complete interview transcript can be found in Appendix H.

### **3.2.2 Focus groups**

On completion of interview 2 with participants from cohort 1 (my first group of participants) I reflected on the nature of the planned data collection approach, with its reliance on individual researcher-participant interviews where there is no participant-participant interaction. I modified the data collection plan for cohort 2 to include a focus group (Silverman, 2011; Kvale and Brinkmann, 2009; Bloor et al., 2002; Morgan, 1997). Focus groups emphasise interaction between participants, with the researcher acting as a facilitator of a group discussion, and are distinct from a group interview, where the focus might still be on researcher-participant interaction (Belzile and Öberg, 2012). The purpose of a focus group is not to establish a group consensus about the issues discussed (although that may occur naturally), but to facilitate participant-participant interaction to “bring a number of different perspectives into contact” (Morgan, 1997, p.46). By minimising researcher-participant interaction, and trying to create what Kvale and Brinkmann call a “permissive atmosphere” (Kvale and Brinkmann, 2009, p.150), I wanted the participants to become more aware of their hidden assumptions and to compare and discuss their views. Although cohort 1 had by this time completed the SKE course and become PGCE students, I decided to also include a focus group between interviews 3 and 4 (see Fig. 10 on p.47) to see how this cohort’s PGCE experience played a part in their discussions about subject knowledge development.

Each focus group lasted for approximately 90 minutes, was audio recorded and later transcribed, and took place at Albion University. A separate focus group for each cohort of participants was held (David was unable to participate due to illness) as I wanted to enable the participants to draw on their shared experience of the course as part of the same student cohort. Focus groups consisting of participants from both cohorts may well have yielded useful data, but time and logistical constraints prevented this. During each focus group I asked each participant to individually construct a diagram of the physics subject knowledge needed by a physics teacher (the same task as used during the individual interviews). The diagrams were then shared and

discussed in the group. In addition, I asked the participants to agree collaboratively what the key elements of physics subject knowledge for a teacher are, and to write these on post-it notes (see Appendix B for a focus group schedule). They were then able to arrange these elements while discussing their relative importance.

### **3.2.3 Initial study**

Interviews 1 and 2 with cohort 1 were conducted as an initial study (Gray, 2014; Barbour and Schostak, 2005), where the data collection processes were reviewed and refined in preparation for ongoing data collection from cohort 1 and the start of collection from cohort 2. The initial study led to some minor changes to how the interviews were conducted rather than significant changes to the questions themselves. For example, the time spent on explaining the research and putting the participants at ease was reduced as it became apparent during interview 1 that I was spending too much time on this. I also allowed myself to ask questions in a different order from what was planned according to how the participants talked about their experiences. This meant that a question could be revisited more than once during later interviews compared to my attempt to address each question sequentially during the initial study. In addition, as discussed in section 3.2.2, the initial study led me to plan to conduct a focus group with each cohort.

### **3.2.4 Participants**

The nine original participants had an age range of 21 to 30 years old and came to the SKE course with a diverse range of prior educational and professional experiences. They were all from England, Northern Ireland or the Republic of Ireland, and out of the original nine participants, two were women. All 21 students on the 2011/12 and 2012/13 SKE courses were invited to participate and all those who volunteered were accepted, i.e. my 'sampling strategy' was convenience sampling (Cohen et al., 2011, p.155) and non-selective.

I am aware that the 'stories' I am presenting about the participants, and my interpretations of their data, are created by me as the researcher, as someone who is situated in the research setting. I am therefore reluctant to describe the participants as a *sample*, in the scientific sense of a representative subset of a larger set of potential participants. I wanted to pay attention to what is unique about the self-constructed conceptualisations and self-reported experiences of each participant. I make no claims to the participants representing the attributes, conceptualisations or experiences of the entire SKE course student population in the researched institution or across all SKE courses nationally (other than their obvious common attribute of not having a physics Bachelor degree). Instead, I seek to develop insights from each individual participant that may act as an analytical lens through which the experiences of other SKE students can be viewed.

### **3.2.5 Ethics**

The key ethical issue with insider research in this context was balancing the inherent tension between the tutor-student and the researcher-participant relationships. I was clear from the outset that the tutor-student relationship was of primary ethical importance, and that I had to act in the best interests of the participants as SKE course students. For example, I scheduled data collection to take into account the demands the participants would experience during different phases of their SKE or PGCE course. Researching a SKE course at another institution would have avoided many of my ethical concerns. I chose not to do that, partly for practical reasons to do with negotiating access, but also because I initially conceptualised my research as focussing on the lived experiences of *my* students on a course I had inside knowledge of, with consequent implications for my institution's practice.

I introduced verbally the research to the students at the end of an SKE course session and provided them with a letter containing participant information sheets to take away and read. I used an opt-in approach to informed consent (Cohen et al., 2011, p.77; Thomas, 2009, p.150) and reassured the students that their decision about participation would not impact on their progress during the course, or on the support they should expect to receive from me as a course tutor. The

students were assured that the audio recordings would be safeguarded and then deleted on completion of the project, and transcripts and subsequent reports would be anonymized. The ethical guidelines issued by the British Educational Research Association (BERA, 2011) were followed at all times, and I obtained full ethical clearance from both Albion University and the Open University for all phases of the research, including for the later modification of the data collection plan to include focus groups. Ethical approval from the Open University and examples of the participant information and consent sheets can be found in Appendix C (note that the project title changed after ethical approval had been completed).

### **3.3 Analysis**

#### ***3.3.1 Analysis design***

In this research I did not set out to test hypotheses or evaluate against pre-defined criteria. My research was exploratory, requiring an analytical approach that would facilitate interpretation of the data and development of explanatory ideas. Grounded theory (Silverman, 2011; Gibbs, 2007; Charmaz, 2006; Strauss and Corbin, 1997; Glaser and Strauss, 1967) is a commonly-used term that describes such “a theory-generating research methodology” (Corbin and Holt, 2005, p.49). In grounded theory, explanations are developed as a result of repeated and prolonged ‘immersion’ in the data by the researchers. The resultant interpretations are not based on pre-conceived theories, but instead are said to ‘emerge’ from, or are ‘grounded in’, the data themselves. Grounded theory is most commonly associated with Glaser and Strauss (1967), who emphasised the need to be open to emergent themes, even to the point of not conducting a literature review until analysis of data has been carried out, to avoid contamination of the analysis by the researcher’s prior conceptions (Thornberg, 2012; Dunne, 2011). Strauss and Corbin (1997) later placed more emphasis on the use of grounded theory analysis to verify existing ideas, and that people are “active agents” (Charmaz, 2006, p.7) in creating meaning in their social settings, as opposed to simply being the “passive recipients of larger social forces” (p.7).



At a practical level, an essential feature of a grounded theory approach is the simultaneous collection and analysis of data, where the analysis usually involves coding of qualitative data (Saldaña, 2009). Coding is one of the key ingredients of a grounded theory approach, which also includes: the collection of rich data; memo writing; and, theoretical sampling and saturation (Charmaz, 2006). Coding is where a statement or symbol is assigned to selected data to represent an analytical idea (Gibbs, 2007; Silverman, 2011; Saldaña, 2009). Charmaz (2006) proposes asking basic questions such as “[w]hat does the data suggest? From whose point of view?” (p.47) to guide the initial stages of coding. Gibbs (2007) outlines a staged approach to coding, where codes start off as *descriptive*, are then used to *categorise* key ideas and then finally to represent fundamental *interpretations* of the ideas that are suggested by the data. One approach to coding can be to start with a set of pre-selected codes, and then to ‘look for’ cases of these codes in the data: what Gibbs calls a “concept-driven approach” (p.44) and Saldaña (2009) describes as coding with “a priori goals” (p.49).

For my research I wanted to adopt an exploratory perspective of generating codes that are driven by the data (Gibbs, 2007). I chose to follow the approach outlined by Charmaz (2006) of *initial coding* (p.47), where I read systematically through the data and assigned codes to each key point, and then moved to *focussed coding* (p.57), where initial codes were synthesized to aid the development of analytical themes. I then reviewed the data to seek examples that would enable further development of these tentative themes, a process known as *theoretical sampling*. The analysis ended when theoretical saturation was achieved, i.e. where the collection of new data or ongoing analysis of existing data led to no new analytical insights (Gibbs, 2007; Charmaz, 2006).

In the literature a range of coding procedures are outlined, each with their own pitfalls and methodological underpinnings. All appear to accept that whatever coding approach is used, assigning codes and then making them the primary subject of analysis involves reduction of the original data to a more simplified form (hence Kvale and Brinkmann’s (2009) description of coding as “meaning condensation” (p.205)), especially as the researcher has made decisions about what *not* to code (Miles and Huberman, 1994). For this reason, some researchers regard coding as “an

abhorrent act” (Saldaña, 2009, p.47) that distances the researcher from the voice of the participant. I accept that coding requires some data loss, but it opens the way to manageable and sophisticated analysis. I also recognise that the act of transcribing an interview is itself an act of interpretation that requires loss of potentially useful information, such as choosing not to transcribe verbal tics and pauses (Cohen et al., 2011; Kvale and Brinkmann, 2009). To militate against this potential loss of information, I also listened repeatedly to the original audio recordings when making key coding decisions (see the example in Appendix F).

### **3.3.2 Analysis in practice**

I conducted the initial coding by working quickly through each hardcopy transcript, noting down ideas that occurred to me on first reading. I came to appreciate the value of reading rapidly and staying focussed on what the participant was saying, rather than leaping quickly to interpreting what was said. I used gerunds to start each initial code to help “stick to the data [and] gain a strong sense of action and sequence” (Charmaz, 2006, p.49). For example, for this response from David:

- |       |   |
|-------|---|
| Int   | 28:12 So what for you is the difference between the pure knowledge and applied knowledge?   |
| David | The applied knowledge would be things that I consider myself to be better at than pure knowledge. Pure knowledge is the regurgitation in the exam stuff and then the applied knowledge is using physics, <i>doing</i> physics, <i>doing</i> science with physics knowledge, you know, doing practical experiments, doing what physicists do. Physicists don’t just learn things and just write books, they also do physics. |

I applied these initial codes, using gerunds:

- Judging his performance against his self-defined SK categories
- Defining pure knowledge in terms of assessment
- Judging exam-based assessment negatively (‘regurgitating’)

- Defining SK categories in terms of actions ('doing')
- Doing as distinct from knowing, learning, writing

These are not of course the only possible codes that could be applied and value judgements are being made that are not necessarily supported fully by the content of the transcript (such as interpreting "regurgitating" as indicating negative feelings). However, by choosing not to dwell for too long on possible initial codes I was able to look back and see the themes that first came to mind. Once I had gone through the entire transcript I reviewed the initial codes and identified those that were similar. I could then synthesize these codes and start to identify important themes.

During these early coding attempts I wrote notes in my research journal about points of interest as I read through the transcripts (see examples in Appendix D). These *memos* are described by Gibbs (2007, p.30) as a way of "theorizing and commenting as you go...about the general development of the analytic framework", and are regarded as important tools for capturing insights as analysis progresses, insights that themselves could be analysed, i.e. memos are themselves data (Miles and Huberman, 1994). I also stayed alert to the possibility of identifying and applying *in vivo* codes (Charmaz, 2006, p. 55; Saldaña, 2009, p. 74), i.e. codes derived from a word or phrase used by participants. For example, in the transcript extract above, the term "pure knowledge" is used by David in a way that could suggest a significance of meaning *for him* that is different from what others might understand by the term. I could then use "pure knowledge" as a code, defined as "regurgitation in the exam stuff", and look for it elsewhere in David's data. As with other initial codes, this *in vivo* code could then be refined as a result of constant comparison so that it may capture a significant analytical idea from David's perspective.

Criticisms have been made of the supposedly theory-free inductive approach that is claimed by some proponents of grounded theory (Charmaz and Bryant, 2011; Thomas, 2007; Thomas and James, 2006), following the long-established criticisms of inductivism in science (e.g. Popper, 1963), where all observation choices are recognised as theory-laden. In my research, although I

am exploring my participants' experiences rather than testing a pre-defined theory, I do have some pre-formed notions of what I might be looking for based on reviewing the literature about teacher professional knowledge and from drawing on my own professional experience. My research is insider-research (Plowright, 2011; Sikes and Potts, 2008), as a teacher of the participants and co-developer of the SKE course. Not only could I not avoid drawing on my insider knowledge, but it was essential for making sense of some of the participants' responses. My approach is pragmatic in the sense that I am using constant comparative method (Cohen et al., 2011; Silverman, 2011; Thomas, 2009) while drawing on some of the specific methods associated with grounded theory (Saldaña, 2009; Gibbs, 2007; Charmaz, 2006).

Although I made rapid progress with initial coding, managing the quantity of transcript involved proved to be burdensome and I felt overwhelmed by the amount of paper. I trialled the use of NVivo analysis software, but found this constraining. The inability to see more than a small section of transcript on a screen made it difficult to easily move between transcripts to build up an overall picture about possible themes, and to develop a holistic view of a participant's experiences. I tried a different approach and taking one participant's data, one questioning theme at a time, would *free write* (Charmaz, 2006, p.88) memos about my thoughts as I engaged with the participant's responses as a whole. I found this a liberating experience as I focussed on capturing ideas with a view to later re-evaluating them against the data, what Charmaz describes as learning to "tolerate ambiguity" in writing and analysis (p.85). This approach enabled me to be sensitive to possible emergent themes, which I could then look for elsewhere through theoretical sampling.

I returned to working with paper transcripts and used highlighters to colour-code sections that corresponded to four broad categories of content. These categories were not of course the only way in which the data could be 'sliced'. However, they were chosen to provide a practical starting point for coding and memo-writing that related directly to the research questions:

- A. Definitions/explanations of physics and the nature of science (RQ1 and RQ2)
- B. Content and nature of physics subject knowledge (RQ1 and RQ2)

- C. Experiences of the SKE course (RQ3)
- D. Other data, such as biographical information, views about teaching and experiences of learning physics prior to the SKE course

For each participant, I cut up each transcript from the individual interviews into the above colour-coded categories. I then assembled all the sections corresponding to category 'B' for interview 1, all 'B' for interview 2, etc. and attached them onto a roll of wallpaper (see Appendix D). This allowed me to see the category 'B' responses for one participant for all interviews laid out so I could look through them back and forth while open coding and noting key ideas, comparing different sections of transcript as needed. An example extract is shown in Appendix E for Ben's interview 3. Initial codes are shown as a result of early open coding, along with tentative broader themes that were identified from the initial coding. The themes were refined as a result of constant comparison of transcript extracts across all four interviews, and for all participants. The main findings from these categories of data for each participant are reported in chapter 4. The results of analysis of these categories across all of the participants are discussed in chapter 5.

### **3.4 Validity and reliability**

Validity and reliability are two considerations of research design that have been incorporated into social research from scientific research (Thomas, 2009 and 2007). These two issues are addressed throughout this chapter and I will make some brief comments to draw together how they are dealt with.

#### **3.4.1 Validity**

Validity is the extent to which the research findings represent accurately the researched social phenomena, i.e. how 'truthful' are the findings (Cohen et al., 2011; Silverman, 2011). The specific factors that affect validity in my research include:

- a) the extent to which my research instruments produce the data I intend them to produce, i.e. “instrument validity” (Thomas, 2009, p.107)
- b) how I, as the researcher, affect the participants’ responses and their behaviour (sometimes referred to as the Hawthorne Effect)
- c) the effect of my values, beliefs and prior experiences on data collection and interpretation

I discussed in section 3.1 the concerns I had about my dual role as researcher-tutor and how this was resolved when I left Albion University, which relates to validity concern (b) above. As I will discuss in my concluding comments (chapter 6), as far as I can reasonably tell, the participants were comfortable with being interviewed by me. My evidence for this is that they volunteered to participate in the first place, and more importantly, they chose to continue to participate throughout the research. The participants were willing to voice criticisms of the SKE course during interviews. Tom’s decision to withdraw from the research provided some evidence for me that the participants felt able to opt out of participation.

With regard to factor (c) above, I discussed this in chapter 1. I felt some ambivalence about the concept of the SKE course when it was first developed. I am clear that I have no agenda of seeking to portray the SKE course in a positive light, especially as I have not been involved with teaching or developing the course since soon after my research started.

Throughout data collection and analysis I used the following approaches to reduce threats to validity:

- *Triangulation* (using more than one type of data or data source). I used verbal data, from individual interviews and from focus groups, and graphical data, in the form of the participant-drawn subject knowledge diagrams. Collecting data longitudinally also enabled some measure of triangulation, through repeated use of similar questions and clarification during later interviews of earlier responses.
- *Respondent validation* (asking for participants to check and comment on on-going interpretation of data). I did this with the biographical data I collected so that the participants

could check the accuracy of the accounts I constructed. I did not do this for all data, for two reasons. Lack of time precluded this for all data, but I was also concerned about compromising how participants would respond in later interviews if they had been able to read and respond to earlier interview data. During the final interview with each participant, I displayed all of their previous subject knowledge diagrams and invited comment. This enabled me to check my understanding of certain features of their diagrams and what this meant for their views about subject knowledge.

- *Constant comparison* (the checking of analytical ideas and interpretations by looking for, and comparing with, other relevant segments of data). This was used as an integral part of data analysis and is discussed in section 3.3.

### **3.4.2 Reliability**

Reliability is how consistently different researchers, or different data collection and analysis methods, would produce the same findings, i.e. how 'stable' are the findings (Cohen et al., 2011; Silverman, 2011). As discussed in section 3.1, I have adopted an interpretivist methodological stance, a position that some argue is largely incommensurable with the notion of reliability (see for example, Thomas, 2009). However, Silverman (2011) disagrees with this view, arguing that it would "rule out any systematic research since it implies that we cannot assume any stable properties in the social world" (p.361). He summarises common ways of improving reliability and I have noted how they feature in my research approach:

- *Making the data collection and analysis processes transparent* – I have set out my use of methods in chapter 3
- *Use of "low inference descriptors"* (p.361), i.e. using original verbatim data as much as possible in the research account "rather than researchers' reconstructions" (p.361) – I have used verbatim accounts. All verbal data used in analysis was audio-recorded. Re-listening to these recordings and comparing with transcripts was used throughout.

- *Pre-testing of interview schedules* – I reviewed the effectiveness of my interview approaches after interview 1 with cohort 1, and refined my interview questions and technique as much as possible based on the experience gained. I used the same interview schedule with all participants for each phase of interviews to ensure some consistency of approach.



#### **4. Results: “physics is the study of the whole world around us”**

The participating students in this research were individuals with unique experiences during their time on the SKE course. To preserve their individuality I will present in this chapter a summary of key results for each participant from the individual interviews. I will then report a summary of results from the two focus groups. In chapter 5 I will discuss the analytical ideas developed from analysing interview and focus group data about all participants transversely (i.e. themes that extend across all or some participants) as well as longitudinally.

Data from all interviews is included (see Fig. 10 on p.47), so the results shown below for Andy, Ben, Nick and David include data gathered during the PGCE course in addition to the SKE course (see Appendix B for the interview schedule). The individual participant summaries are structured according to the content categories A, B and C (identified in chapter 3 on p.58) that relate to the research questions:

- A. Definitions/explanations of physics and the nature of science (RQ1 and RQ2)
- B. Content and nature of physics subject knowledge (RQ1 and RQ2)
- C. Experiences of the SKE course (RQ3)

A brief pre-SKE course biography of each participant is provided in Appendix G (p.180).

The research questions are:

RQ1 What are physics SKE students’ conceptualisations of physics subject knowledge for teachers?

RQ2 How do these conceptualisations develop during ITE?

RQ3 What do the students experience as significant for their subject knowledge development?

## 4.1 Nick (cohort 1)

### *A. Definitions/explanations of physics and the nature of science*

At the start of the SKE course Nick describes physics in broad terms as “about the world around you” and “the things you see every day”. He identifies what he regards as two distinct areas of physics or types of physics knowledge:

physics does have this split in it about the classical side of things, Newtonian physics, etc. and then Einstein came up with the theory of relativity and said ‘well hang on it’s a bit more complicated than that’ and then went off on a tangent to a whole new branch of physics (Nick, interview 1)

Several months into the SKE course Nick again refers to physics in terms of its explanatory power and possible applications:

I would say that physics is the study of the whole world around us [...] It’s one of three core sciences and it’s the one that sort of explains everything from how the universe started through to majestic, if that’s the right word, things like that through to how light works [...] Even everyday stuff like driving your car and everyday bits of engineering, like mobile phones and the internet. Everything is physics really (Nick, interview 2)

His descriptions of physics start to refer more frequently to fundamental concepts or ideas. He also starts to make a distinction between bodies of knowledge (which are distinctive to each science and essentially define them as discrete subjects) and the process that scientists engage in, which is common to all scientists, revealed in this exchange:

I think that science is a body of knowledge and it’s also a way of thinking. So in terms of the difference between physics and chemistry, physics is obviously a body of knowledge that is physics [...] and the common theme then between the different sciences would be the methodology and the way you go about thinking about doing physics, doing chemistry. There’s still a scientific method, which is the old, like you observe phenomena in the natural world. It could be biological, it could be physical, it could be chemical, and then you come up with a hypothesis, test it again, test it again, and then come up with a theory of, this is why what we’ve observed is happening. So that’s common to all three sciences. (Nick, interview 3)

By the end of the PGCE course Nick now states that when trying to describe physics to pupils “I’d just think about the scheme of work” (Nick, interview 4) and refer simply to content topics. Nick’s descriptions of physics during the SKE course are grounded in his personal experience of it at school. He also appears to hold a view during the SKE course that science is an objective activity which produces results that could have been arrived at by any person at any time when using the same data.

I am imagining with some practicals you can do in the classroom you can replicate, because of the way science is, you can replicate an experiment that scientists have done hundreds of years ago and come up with the same theory from similar results. You could say that this is the nature of science, this is how we *do* science, because of the instructions they have laid down and their method we can replicate that hundreds of years later and it still holds true (Nick, interview 2)

A particular model of scientific method is suggested here that is repeated in later comments about seeing his role as a teacher as enabling pupils to ‘discover’ physics theories for themselves. The idea of the ‘pupil as scientist’ has been much criticised (Hodson, 2014; Hodson and Hodson, 1998; Wellington, 1998), but is commonly found amongst student teachers. It is interesting to see evidence of it in a pre-PGCE student.

### ***B. Content and nature of physics subject knowledge***

Throughout the SKE course Nick discriminates between the physics subject knowledge he thinks he will be learning and what he thinks he will need to know to “engage with children and young people in a classroom environment” (Nick, interview 1). On the subject knowledge diagram he constructed during interview 1 (Fig. 11) he indicates this by the vertical dotted line. The area to the left consists of factual physics content knowledge and this is what everyone who is learning physics has to know. Nick further divides this content knowledge into “classical physics” and “modern physics”, a division he has determined from prior reading as significant in the history of physics.

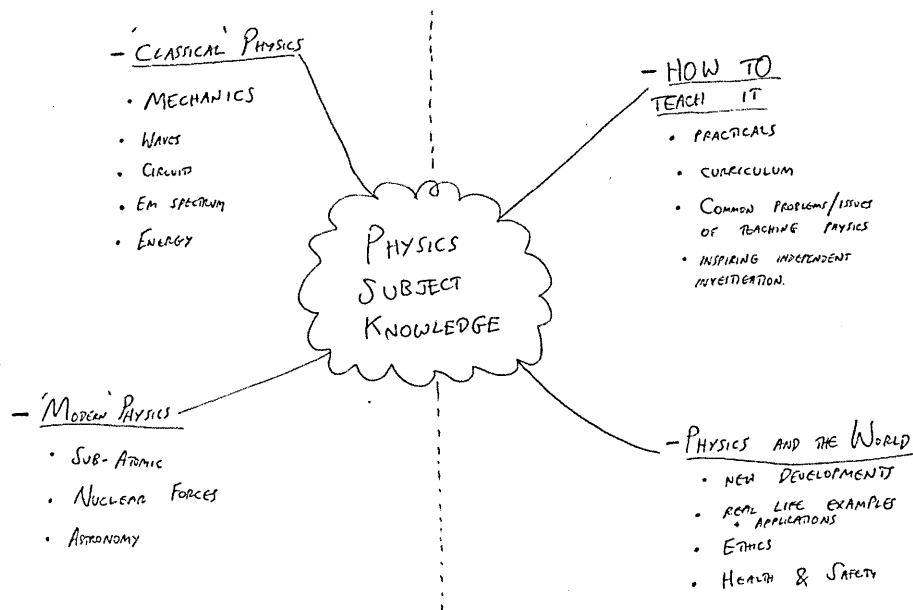


Fig. 11: Nick's subject knowledge diagram for interview 1

Several months into the SKE course, Nick now identifies three categories of subject knowledge (see Fig. 12). He first talks about needing knowledge of everyday examples of science and scientists (he does not refer to only physics and physicists) and how this has been influenced by his experience of the Science and the Public SKE module. For Nick, “that’s the way science in schools is going”. He states that there “still has to be a heavy emphasis on theory”, adding to his diagram what he calls “core concepts”. The “modern” and “classical” physics binary view is still evident, only this time Nick is clear that this binary split provides

a nice way of looking at it because you get the human elements, the historical context of when this physics was discovered (Nick, interview 1)

Although in interview 1 Nick identified “inspiring independent investigation” as an element of subject knowledge, he did not expand on this verbally. In interview 2 Nick discusses the role of practical work, placing emphasis on a teacher knowing how to support children to “discover physics for themselves”.

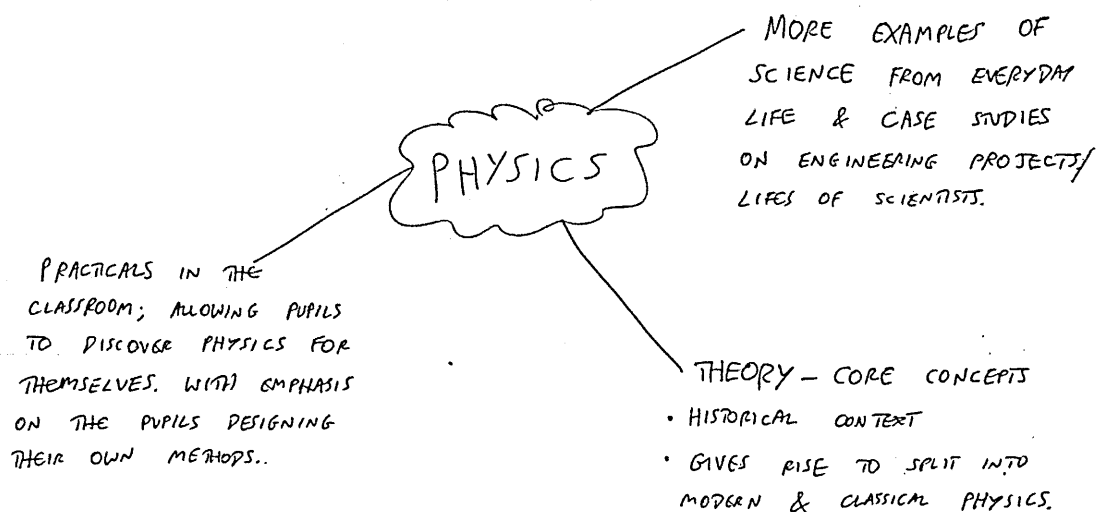


Fig. 12: Nick's subject knowledge diagram for interview 2

At the start and end of the PGCE course (interviews 3 and 4) Nick continues to give prominence to factual knowledge of discrete physics topics. At the start of the PGCE course, Nick starts his description by stating "I'm going to stick with the structured approach" and then designing a diagram, very similar to Fig. 11, based around the ideas of "classical" and "modern" physics. The influence of the Science and the Public module is apparent as he talks about needing to know "history of physics", but gone is the explicit emphasis on pedagogical knowledge. Instead, it appears for Nick that learning how to teach physics is something that he needs to do, but this is separate from what he regards as physics subject knowledge. By the end of the PGCE course, Nick's view of subject knowledge appears to have crystallised into factual knowledge of the curriculum topics to be taught (see Fig. 13). He no longer talks about "classical" and "modern" physics, but instead states that

physics is all these things because that's what I'm going to be teaching [...] and then for me, as a physics teacher, obviously that's what I'll need to know (Nick, interview 4)

The pedagogical knowledge he describes in previous interviews is still important, but Nick has removed them from what he thinks is essential about physics subject knowledge, which is the factual content knowledge specified in the curriculum.

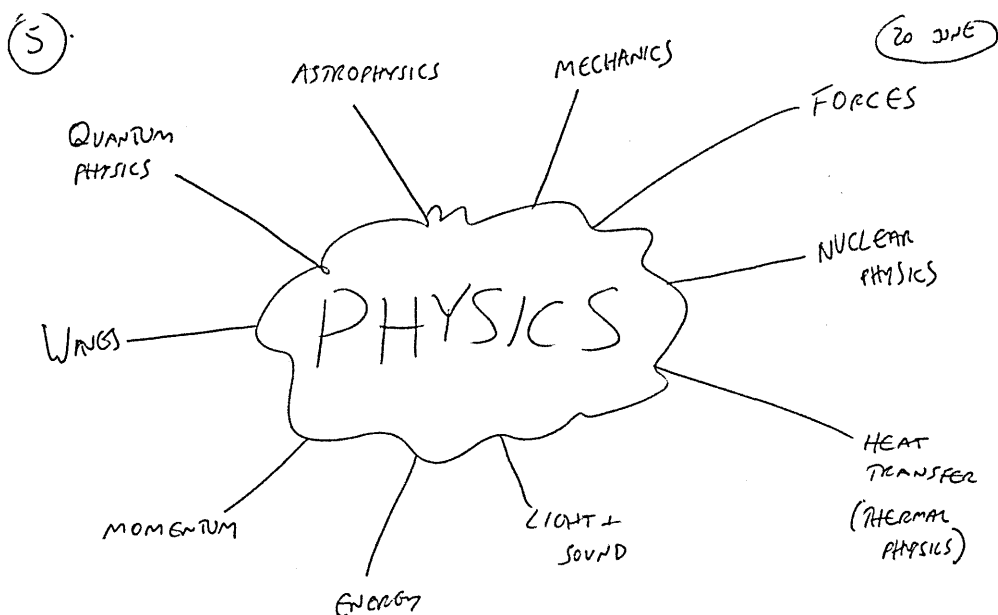


Fig. 13: Nick’s subject knowledge diagram for interview 4

Nick states that there is a minimum amount of predetermined subject knowledge that needs to be acquired during the SKE course and “the purpose of this year is to get our knowledge base up to where it needs to be to start the PGCE” (Nick, interview 1). When asked about what makes a teacher’s subject knowledge distinctive from that of other professions, for Nick it is possession of “broad brush knowledge”. This broad brush knowledge is not only “general knowledge of all of the physics concepts that are out there” (Nick, interview 1), but it is not acceptable for a teacher to be ignorant of any aspect of this knowledge when teaching. For Nick, he will know when he has acquired ‘sufficient’ subject knowledge when his broad brush knowledge will enable him to answer any unanticipated questions that might come up in the classroom. Broad brush knowledge is a useful operational concept for him and he provides specific examples of what he means by it:

you just need to have maybe an awareness for talking about some case studies about what’s going on at the moment. So, the other day the A350 airbus was launched and I was saying to the lads someone will have done something on simple harmonic motion as to how wings vibrate and is it within certain tolerances or something like that. So, just in addition to that I put an awareness of contemporary stories. (Nick, interview 4)

### ***C. Experiences of the SKE course***

Nick started the SKE course expecting to develop what he refers to as his “knowledge base” (Nick, interview 1) of physics up to a minimum level required for the PGCE course. He also expects to be exploring “the bigger picture and what we are going to be doing in two years’ time, i.e. actually in the classroom” (Nick, interview 1). Although he does not articulate any specific expectations of what this might involve, towards the end of the SKE course he identifies the need to “develop our way of explaining physics” (Nick, interview 2) as what he wants more of during the course. What Nick enjoys most is learning to relate physics concepts to everyday situations, something he valued as a learner before he became a student teacher. He recounts the example of suddenly understanding an aspect of forces in the context of circular motion while watching a video of a fairground ride during a SKE session, and also shares a vivid insight into his understanding of electricity:

This is going to sound pretty weird, but over Xmas I was out walking with my girlfriend and there was an electric fence which I accidentally touched and got quite a big shock. You can’t really appreciate that, when we talk about these concepts of energy and it is easy to understand that a moving mass has kinetic energy or gravitation and potential energy, but it is difficult to appreciate moving electrons in a piece of wire. Like, you look at it and think what is going on there, but you realise that electricity does have this energy which you can calculate with different equations, but that was a bit of a revelation for me. I actually appreciated it. (Nick, interview 2)

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## **4.2 Ben (cohort 1)**

### ***A. Definitions/explanations of physics and the nature of science***

I always think of physics as one of the more abstract sciences... I’d say you are learning about the physical laws, the fundamental physical laws of nature that govern how things work, how things interact with each other, why things do what they do, why a car moves down the street at such a speed or whatever and basically examining those principles or trying to understand them (Ben, interview 1)

During each interview Ben talks about how difficult he finds it to define physics without “sounding really vague” (Ben, interview 2), but he does share a personal definition of physics that is constructed around it as ‘abstract’ knowledge that is governed by ‘rules’. He consistently describes physics by first defining biology (“the study of living things”) and chemistry (“to do with the reactions of substances”), and then defining physics in terms of what the other sciences do not cover (“physics is everything else really”) (Ben, interview 2). Several months into the SKE course Ben defines physics as:

everything about physical order, about how things move. Phenomena such as radiation and light, kind of thing (Ben, interview 2)

At the start on the SKE course Ben begins his explanations of physics by referring to his own experiences and impressions of it (e.g. physics is “tactile”, “harder to get your hands on”, “challenges your everyday ideas”). As he progresses through the SKE and then PGCE courses his definitions rely less on his own emotional experiences and become more depersonalised.

It’s a way of looking at the way that objects interact, looking at the forces between them and the effects that forces have, the effect of temperature, of motion, I’m struggling (Ben, interview 3)

it’s looking at the way that the world works, the way sort of objects interact with each other and trying to make sense of that based on sort of experiment and evidence and trying to use that to predict how things or objects will behave using the evidence that we’ve got from previous experience. (Ben, interview 4)

Although Ben refers to “topics” in his definitions of physics during the SKE course, this occupies a relatively small proportion of the language he uses. In interview 1 Ben describes what someone would learn about when studying physics, which amounts to learning the “fundamental physical laws of nature [and] examining those principles or trying to understand them”, i.e. the laws are presented as factual knowledge that constitutes the subject of physics, and they are to be “examined” and understood. Later in the SKE and PGCE courses there is a change in the language Ben uses, which is now dominated by action words (e.g. “physics is looking at the physical world to make connections and trying to explain”, “physics is an attempt to model”). He uses words



such as “looking”, “attempt” and “try” several times during his explanations. This suggests a view of physics that develops from it being dominated by *content* or *factual knowledge* towards physics as a *process*. In all of the interviews it is evident that Ben is thinking about his physics subject knowledge development in the context of needing to make it “good for the kids” as a teacher.

**B. Content and nature of physics subject knowledge**

During interview 1 Ben brings to the course a preconceived model of physics subject knowledge as factual content organised into traditional topic areas (e.g. waves, energy and forces) and how to explain these topics to others (“conferring that knowledge onto other people”). These two elements are “being bundled together into one sort of package” during the SKE course. As a result of his initial SKE course experience he also now tentatively includes what he calls “how science is” and “how it relates to the world”

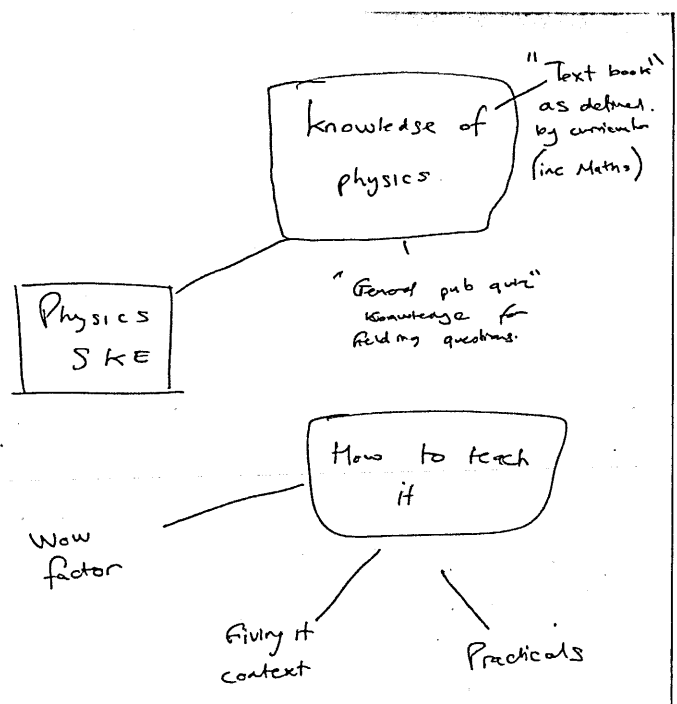


Fig. 14: Ben’s subject knowledge diagram for interview 2

In interview 2 (several months into the SKE course) Ben’s model of subject knowledge (see Fig. 14) is still structured around the dualism of “knowledge of physics” and “how to teach it” (i.e.

pedagogical knowledge). However, Ben's "knowledge of physics" has now developed from the knowledge of traditional topics in interview 1, to knowledge of "what the kids have got to learn to get through the curriculum". For Ben, the "how to teach it" knowledge is physics-specific, consisting of knowledge of how to place the physics in context, how to teach it through practical work and how to make physics interesting to children. Ben introduces knowledge of what he calls the "wow factor", which is teaching approaches that will place physics concepts into exciting contexts, such as the Monkey-and-Hunter demonstration for teaching projectile motion and using a van de Graaf generator for exploration of electrical phenomena. His conception of subject knowledge is organised around the needs of the children who will be learning it and that it is a body of knowledge that he needs to acquire until he has enough to be able to do this. As the interview progresses Ben goes on to identify two types of factual subject knowledge: "textbook", which is the "subject matter for the course" as defined by a curriculum, and

there's more of a general sort of pub quiz type knowledge... It's just sort of general interesting facts or little quirks, and things like that...you wouldn't necessarily find in a textbook (Ben, interview 2)

The significance of these types of knowledge appears to lie in forming the basis for criteria for Ben knowing if he has sufficient subject knowledge. Ben describes the need to feel confident about being able to deal with questions children might raise that might be "above and beyond what they necessarily need to learn". This seems to be the source for Ben's "pub quiz" knowledge, which is "good broad knowledge" that he would be able to "rattle off"

because really you want to be able to answer everything that they can throw at you, don't you? (Ben, interview 2)

Text book knowledge represents the knowledge that can be prepared in advance of needing it in a lesson, while "pub quiz" knowledge cannot be prepared in advance, and is required unexpectedly in a lesson situation. A second criterion he introduces is "fluency", where you can readily make connections between concepts when constructing explanations:

I guess the more fluent you get with the subject the more angles you will have to come in from. (Ben, interview 1)

He describes this as a level of understanding that is above what is needed for personal understanding and where “less of a conscious effort” is needed to talk about concepts. Ben uses the ideas of *fluency* and *pub quiz & textbook knowledge* to structure how he conceives of subject knowledge as he progresses through the SKE and PGCE courses. At the start of the PGCE course (interview 3) Ben divides subject knowledge into “factual knowledge” and then how the elements of this factual knowledge relate to each other (see Fig. 15). Most of his description of subject knowledge consists of knowing how to explain physics to children. This pedagogical knowledge includes understanding of misconceptions, both children’s and his own as a learner of physics. Again, *fluency* is included even though it is clear from Ben’s descriptions that this provides a criterion for having sufficient subject knowledge rather than representing a distinct type of knowledge.

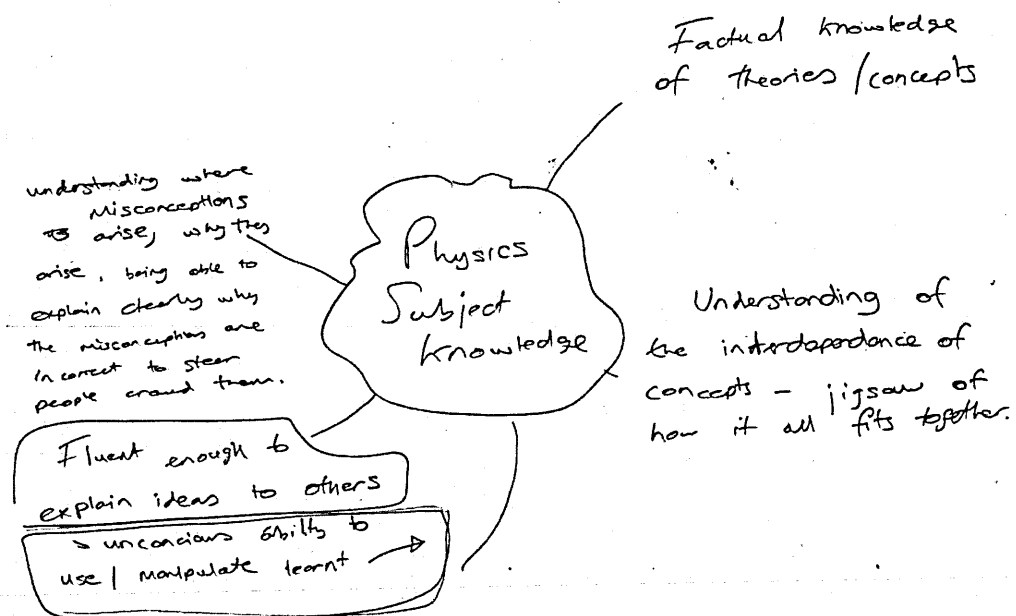


Fig. 15: Ben’s subject knowledge diagram for interview 3

At the end of the PGCE course Ben refers back to the diagram he drew during the focus group a few weeks earlier (Fig. 16) as “quite complete for me at the moment”.

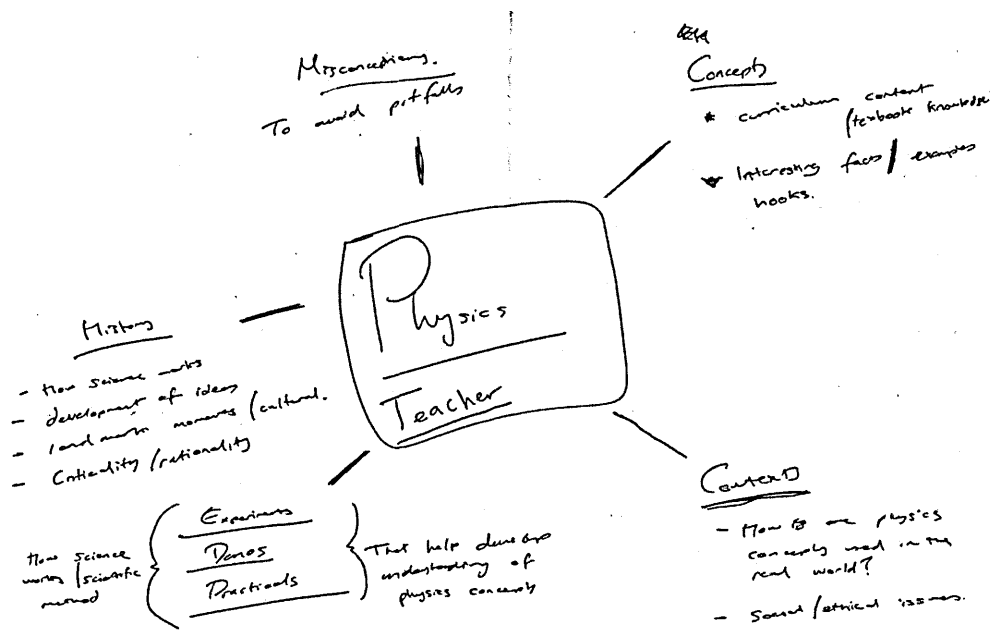


Fig. 16: Ben's subject knowledge diagram for interview 4

All of the key elements identified during the previous interviews are present. Although *fluency* is not written on the diagram, Ben refers to this again as a significant aspect of a teacher's subject knowledge and describes a teacher he worked with during his school-based placement as demonstrating it:

...it's just that being at ease with it, being confident, having enough knowledge to be able to do that.

And you see teachers who are really good at that. There was one guy who just sort of rocks up to every lesson with his board marker – he's a deputy head actually - and he just rocks up with his board marker, looks at what he's supposed to be teaching then he's... I guess he's done it for so many years he can just do it there and then [...] and he is so sort of fluent with this subject knowledge that he's able to also make it fairly engaging and entertaining at the same time. (Ben, interview 4)

### C. Experiences of the SKE course

During the SKE course (interviews 1 and 2) Ben explains that returning to formal education after six years of travelling or employment has been enjoyable and he “really appreciate[s] having someone there whose job it is to just teach us stuff”. He identifies the “peer-teaching sessions” as a valuable because they require him to break down an explanation of a concept into its “simplest form”, and also are a “good confidence booster for coming into teaching”. Although Ben identifies

the dual value of peer-teaching approaches for developing knowledge of subject content and knowledge of pedagogy, he is aware that he likes to experience a didactic approach, where there would be more “tutor-led sort of death by PowerPoint sessions”. However, Ben does not want to be a passive receiver of a tutor’s knowledge or only learn physics through studying recommended texts:

maybe some people can just read a textbook and photographically memorise it, but for me having somebody talk about it and explain it and be able to fire questions at is a much more efficient way of learning (Ben, interview 3)

Ben also highlights the value of having two tutors teaching separate sections of the course as he has been able to experience “very different styles” of teaching, which has informed his reflections on how to teach physics. His views about the SKE course do not change as he progresses through the PGCE course. He continues to identify, during interviews 3 and 4, peer-teaching approaches as valuable, although he would have liked “a bit more, sort of, hard core theory after it as well” (Ben, interview 3) from a tutor. Ben is consistently critical about the Science and the Public module, which he describes as “a waste of tutor time”:

We’re here on a SKE physics. We’re not here on a popular science SKE course and I don’t see how that’s going to really benefit me in the coming years of teaching. Maybe I’ll be surprised, I don’t know (Ben, interview 3)

He would rather have used the time on “learning physics in greater depth” and does not see it as having an important part to play in his development as a physics teacher. When he reflects on what he learned overall from the SKE course Ben states that he did not learn any new physics from when he studied it at A-level, but the SKE course...

...made me remember it all. I probably understand it now better than I did at the end of my two year A-level and we have done just one year of the SKE course. I think I have probably just achieved more in that year in terms of progressing my knowledge and understanding, but I don’t seem to have these light bulb moments, not in physics anyway. It just been a gradual accumulation of things and then the fitting together into what has seemed like different concepts being part of each other and threaded together

that came through, but I think that was from the course as a whole, that was a holistic thing, it wasn't a bang 'oh yeah, that's what it's all about' (Ben, interview 3)

### 4.3 Andy (cohort 1)

#### *A. Definitions/explanations of physics and the nature of science*

Andy's descriptions of physics are constructed around the idea of the study of "interactions" and as a subject that is applied to "the real world". At the start of the SKE course Andy's definition of physics is

the interaction of particles in some sort of way through things like forces and, yeah I'd say it's something to do with particles (Andy, interview 1)

He refers to examples to illustrate what he means, such as describing electricity as a movement of charged particles and analysing the opening of a door through the idea of forces. The idea of *interaction* features strongly in Andy's descriptions (he uses the term across the four interviews thirteen times when defining physics). For Andy the other sciences involve seeing phenomena happen, such as in chemistry where "you put the chemicals in, you see that happening, you see the intermediate sometimes and then you see the end results", whereas physics is about seeing two stages of a phenomenon and

it's the understanding of what's happening between those two items. Because, you know, if you've got Newton's Cradle you've got one ball hitting another ball. Most people think, one ball hits the other ball, it hits the other ball and the other ball goes flying. When you think about it in the physics aspect, you're thinking well there's a change of energy, there's a transfer of energy. There's a change, you know, in energy from kinetic to potential energy. (Andy, interview 1)

The distinction between the sciences is "more or less just the areas that they cover", which appears to refer to content knowledge. Andy states how difficult he finds it to define physics during the interviews, as it is

one of those weird questions where you know what it is but you can't put it down (Andy, interview 1)

This struggle to define physics seems more of an issue for Andy later during the SKE course (interview 2), when he describes physics simply as “not like the other two science subjects” as it is “understanding the world better”. Once he starts the PGCE course (interview 3) he still describes physics in comparison to chemistry:

The differences are more or less just the areas that they cover, so when you’re going into chemistry it’s more material... it’s things like interactions between atoms – which is covered in physics but it’s kind of when you get two atoms combining into another molecule that’s more chemistry than physics, although when you get physics with particles – interactions between particles and the particles they exchange as they interact (Andy, interview 3)

By the end of the PGCE course (interview 4) Andy’s definition has become:

physics is an aspect of science based in logic and mathematics which deals mainly in interactions between objects. [...] that’s mainly what physics is about. It’s interactions between two or more, many objects, you know, for instance, you’ve got gravity, that’s an interaction between an object and a celestial body of some sort. Usually the earth. You know when you’ve got elec-, when you’re talking about electrical charges you’re going to be talking about two, you’re going to be talking about objects interaction in, interacting in some way. They don’t have to be touching, but it’s going to be some form of interaction. (Andy, interview 4)

*Interaction* is a significant idea for Andy in how he thinks about physics. He is open about how much he struggles to articulate a clear description, a struggle that is evident throughout his SKE and PGCE course experience.

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## ***B. Content and nature of physics subject knowledge***

At first glance the subject knowledge diagram Andy constructs at the beginning of the SKE course is complicated (Fig. 17), with many interconnected items. During this first interview, Andy constructs his diagram starting with “knowledge of the subject” and then “understanding of the subject”. Knowledge for Andy is being able to “remember” information about the “topics”, which he then adds to his diagram, whereas to understand requires knowing “why or what or how” and being able to “apply” that understanding:

So if I said, you know, Newton's 3<sup>rd</sup> Law says this, well, most people can remember that. Most people can read the sentence and go, right, I know that, but it's *applying* that, you know, I've read Newton's 3<sup>rd</sup> Law so here's a question on Newton's 3<sup>rd</sup> Law can you apply it to it. Can you apply what you *know* to the question in this situation. It's that difference, knowledge is, I wouldn't say easy, it's easier to gain knowledge than to understand it. (Andy, interview 1)

Andy then distinguishes between being able to apply knowledge to the "real world" and "theoretical scenarios", although he does not explain why he makes this distinction and how they are different from each other. He then identifies what he calls "linking to other areas not normally linked to physics". When asked to give examples of what he means by this he explains:

Things like blood moving through the body. You know, you've got pressure difference in there. [...] Things like biological systems and how they interact. Chemical systems and how they interact. You know, when molecule A hits molecule B there's physics involved in that. Most people go through, you know, A hits B equals C and don't really think about the physics interaction between them. So just applying that physics situation. (Andy, interview 1)

It is not clear how this subject knowledge area differs from "applying to real world" and Andy's struggle to do so is likely a consequence of having to 'think aloud' during the real-time construction of his diagram, without having had time to develop his ideas. Despite this, the idea appears to have some meaning and value to Andy as he continues to make explicit links between it and other areas of the diagram in a way that is distinct from the links made with "applying to real world". Finally, Andy adds "being able to communicate ideas to others".



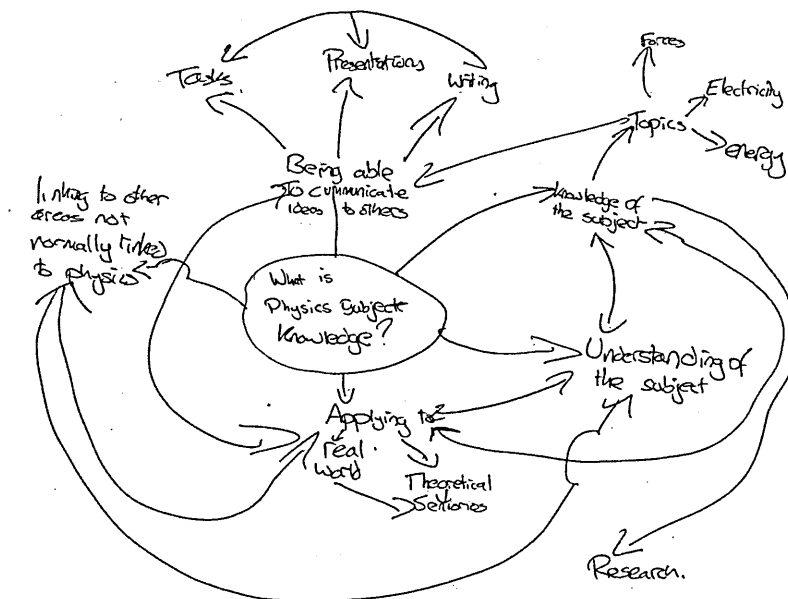


Fig. 17: Andy's subject knowledge diagram for interview 1

Later in the SKE course, during interview 2, Andy's descriptions of subject knowledge are brief and less complicated compared to interview 1. He refers briefly to the need to "know and understand the subject", but in the context of being able to use this knowledge to make the subject "interesting". Andy's descriptions suggest a view of subject knowledge as knowing how to explain rather than knowledge of content

When it comes to teaching on your own you're going to be the only one there, you're going to be the one that everybody's focussed on, so it's learning how to be able to present your ideas confidently and help others understand confidently. (Andy, interview 2)

His responses reveal perhaps some anxiety about being able to perform as a teacher rather than knowing enough content knowledge. During interview 1 Andy tends to use the term *teacher* as a hypothetical third person. In interview 2 Andy uses "I" more, and refers to his experience as a learner, as if he sees himself as the teacher at the centre of the subject knowledge discussion in this interview.

By the time of the PGCE course (interview 3) there is a change in how Andy talks about subject knowledge. His discourse is permeated throughout by the underlying theme of what Andy calls 'science in the media'.

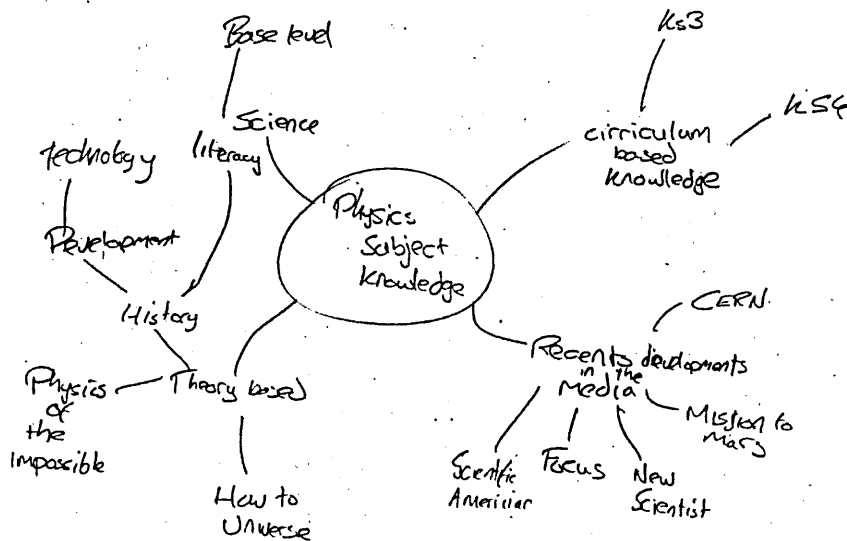


Fig. 18: Andy's subject knowledge diagram for interview 3

He describes first “curriculum based knowledge” (Fig. 18) as:

the base level, especially at Key Stage 3 level [...] Key Stage 3 is a more generalistic coverage of physics, and then when you start advancing from Key Stage 3 onwards it starts getting more and more focussed. (Andy, interview 3)

“Recent developments in the media” and “theory based” knowledge occupies most of the discussion, with Andy providing many examples, adding them to the diagram as second-level items. Examples of science in the media which explain scientific concepts and advances, or apply science to novel contexts, are captured by “theory based” knowledge. “Science literacy” requires some explanation. It is

the base understanding. It's like the underpinning model of all the theories. So when you go into physics you've got to understand basic concepts like forces, energy, particles, to kind of underpin all the other stuff. So if you're to study something like, let's stick with the particle accelerator, you've got to understand particle theory, you've got to understand some form of energy. To have a basic understanding you've got to understand that. You have to have a basic knowledge of nuclear physics just to get a grip, even a loose grip, onto the concepts that are surrounding it. Obviously it can get quite advanced but you need a base understanding. It's like a level as it were from not having knowledge to having knowledge; you need a base level to start from. (Andy, interview 3)

This looks like understanding of factual content knowledge, although it is not clear how this relates to “curriculum based knowledge” in Andy’s mind. Later in the interview Andy clarifies the relative importance of the items drawn in Fig. 18:

I would say the main thing that captures it is the scientific literacy and the curriculum based knowledge, they kind of encompass physics subject knowledge as I’d kind of understand it. But the other bits are necessary as well but they’re kind of another stage up. (Andy, interview 3)

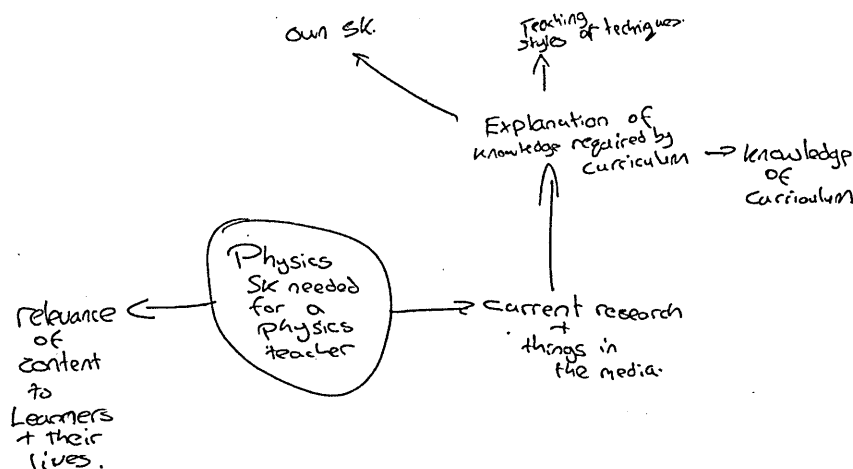


Fig. 19: Andy’s subject knowledge diagram for interview 4

At the end of the PGCE course, Andy’s model of subject knowledge draws together many of the ingredients that feature in different places during the previous interviews (see Fig. 19). He appears less hesitant in articulating what his views now are, and his views are oriented around being able to explain physics and engage learners. He identifies first “current research + things in the media”, which is “an important aspect of subject knowledge and it’s stuff kids actually want to learn about”. This is linked to “the explanation of knowledge required by the curriculum” of which his personal knowledge of physics is a sub-category along with “teaching practice...techniques, teaching techniques and styles”. His experience during the SKE and PGCE school-based placements leads him to identify how to make physics content relevant to children:

I’ve heard quite a lot of, you know, “Why do I have to learn this? What’s the point in this?” It’s relevancy that needs to be translated across. (Andy, interview 4)

Andy summarises physics subject knowledge as:

You need to know facts, facts and information are clearly important in it's what the learners need to, you know, get their qualifications, pass their exams, do their assignments. The important part of your own subject knowledge is not only knowing that but knowing how to deliver that, how to explain that in a way that they will get, they will get, it will translate across. (Andy, interview 4)

When asked more about "own subject knowledge" Andy answers this by describing a *process* he now goes through when preparing to teach, rather than recalling or accessing a body of knowledge.

Any area where I've, you know, where I've been told, you know, "You're teaching this," and I've looked at the scheme of work [...] and then looking at the resources that are out there and thinking, you know, looking at it and going, "That's not going to work, that's too much information to, all at once," or, you know, "That's a good resource, that's plenty of information, but it's too soon". (Andy, interview 4)

### ***C. Experiences of the SKE course***

Andy identifies consistently across all of the interviews four aspects of the SKE course he experienced as helpful. During interviews 2 and 3 he highlights the Science and the Public module as significant (it dominates his responses during interview 2) for preparing him to deal with children asking "why are we doing this? What's the point in this?" when they are studying science. He initially describes this during interview 3 (the start of the PGCE course) as "the most important thing" he experienced, although as this interview progresses he identifies other aspects of the SKE course that were at least as important for him. One was the range of assessment tasks during the course, and the feedback received about his responses in particular. The other is the emphasis on group work that involves explaining physics concepts to peers. By the end of the PGCE year (interview 4), Andy looks back at the SKE course group work and is aware of how experience of asking questions of peers, and having to deal with peers' questions aimed at him, has enhanced his understanding of the relationship between his own subject knowledge and his use of questioning during his teaching practice:

It's thinking of the questions you're going to ask the learners, to assess their knowledge, so it's knowing your physics knowledge enough to know where questions could be asked, how the questions could be asked [...] I found quite a lot of the stuff that I experienced on the SKE course, I found that emerging in my own teaching practice (Andy, interview 4)

#### **4.4 David (cohort 1)**

##### ***A. Definitions/explanations of physics and the nature of science***

At the start of the SKE course David describes physics as “what is underneath everything” and defines it as

the fundamentals that makes the world the way it is. How the world works. The framework on which everything happens like the laws of physics for example. Things generally obey the laws of physics so that's how I picture physics in my head. (David, interview 1)

He goes on to explain how physics relates to the other sciences:

I guess physics is in some ways, I don't want to say simpler because it is not easier, it is like fundamental to, you can learn in biology muscles and how nerves make things moves and stuff, but physics explains why, through movement and forces and friction. (David, interview 1)

After several months on the SKE course David explains that his views about physics have not changed and it remains for him:

Physics is the science of how things work. It is a set of rules for everything to work by [...] Electricity obeys certain rules about the relationship between voltages and currents and resistance, it has to flow around a complete circuit. It's things like that. (David, interview 2)

During the PGCE course David talks more about how physics relates to the other sciences. What the sciences all share in common is that they are “all about understanding things that are observable in the world and making theories or laws ... about how they work” (David, interview 3). Physics is like “your underlying operating system for the universe”, with its emphasis on the “rules and theories” that explain how everything works, unlike biology, which “has to include

something that is living”, and chemistry, which is specifically looking at “substances reacting”.

David’s use of the idea of a study of *rules* is consistent in his descriptions of physics throughout the SKE and PGCE courses.

**B. Content and nature of physics subject knowledge**

During the first interview, David starts by organising his diagram (Fig. 20) around the terms “learning” and then “understanding”. He then adds “explaining” and “improving” as sub-areas of “understanding”. As he writes these headings David explains:

First I did that subject [knowledge] is about learning but also about understanding because they are different. You can learn the stuff on the course and learn the facts and the formulas, but what’s important to us is eventually next year as student teachers we need to understand how and why and we need to explain to other people and also analyse our own learning so we can learn how to analyse other people’s learning as well. (David, interview 1)

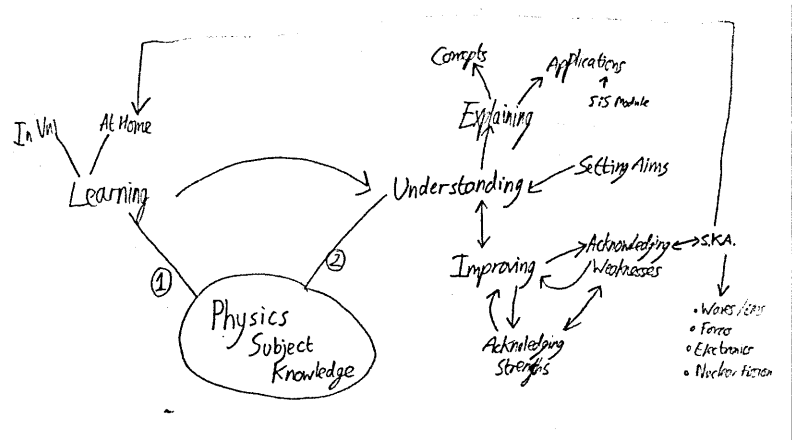


Fig. 20: David’s subject knowledge diagram for interview 1

As he explains his thinking, it becomes clear that David’s evolving diagram is a mixture of describing a *process* he expects to undergo during the SKE course and the content he expects to learn. When asked about “learning” David replies:

I remember like when I was learning GCSE History that was about learning facts and then repeating them later, but with the science you also need to be able to understand the concepts so you can apply them to other situations and apply them in the future (David, interview 1)

He identifies learning how to explain physics as an essential area of subject knowledge, which he learns through his experience of how physics is taught during the SKE course itself.

When I was at school learning physics I was learning it in order to answer questions. For example you learn that velocity equals distance divided by time I was learning it so that when I got into the exam I could put 20 and 10 in and come out with 2, but when we're doing it on the course, when you're writing on the board  $v=s/t$  I find myself thinking about how you are explaining it to us and the steps that lead you through to understanding it [...] and now I'm thinking about how I would explain it and not skipping steps in my head (David, interview 1)

Several months into the SKE course, during interview 2, David now constructs a simpler model (Fig. 21) that retains the key features of knowledge of “content” (which is sub-divided into “facts” and “concepts”) and knowing how to explain physics. However, his model is now a statement of the knowledge needed by any physics teacher in contrast to how he thought during interview 1, where his model was about *his* subject knowledge and partially about the processes of developing it.

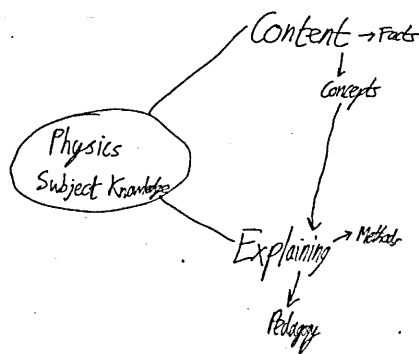


Fig. 21: David’s subject knowledge diagram for interview 2

David explains his distinction between “facts” and “concepts” by drawing on his experience as a learner during his BSc:

I personally have always been better at understanding concepts than facts and the way I distinguish between those is, when I was at university I did neuroscience. I was really bad at neuropharmacology. I was bad at learning the names for things. Like, here’s a drug and here’s what it does to your brain and to your nervous system. I was good at, if you have a stroke this is what happens in your brain. You know,

like, conceptual things. So I guess in physics it would be, facts would be things like the formulae and I find those quite difficult to learn off the top of my head, but concepts would be the application of what you have learnt. (David, interview 2)

He justifies identifying “explaining” as of equal weight with “content” in his diagram by stating that learning “the best methods for explaining things” should not be achieved by student teachers through “trial and error”, but should be learned as part of their formal subject knowledge development.

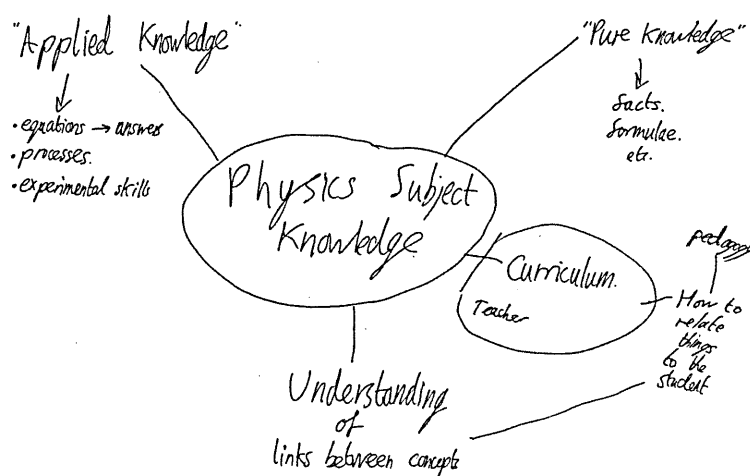


Fig. 22: David’s subject knowledge diagram for interviews 3 and 4

At the start of the PGCE course (interview 3) David’s approach to characterising subject knowledge at first sight is quite different from several months previously (see Fig. 22). He begins by specifying a need for “applied” and “pure” knowledge, where:

Pure knowledge is the regurgitation in the exam stuff and then the applied knowledge is using physics, *doing* physics, *doing* science with physics knowledge, you know, doing practical experiments, doing what physicists do. (David, interview 3)

He then identifies “understanding links between concepts”, which is:

about knowing how it all fits together and knowing, I guess, how it fits within the paradigm, to use a Kuhn-ism {laughs}, how it fits within the whole picture of how physics works, how it fits with other sciences, how it fits with the world, and how it fits with applications up here {pointing to “applied



*knowledge*”). It’s kind of like this is a kind of thing that surrounds all these individual facts so you’ve not just got random facts (David, interview 3)

It looks as if the “facts” and “concepts” ideas expressed during interview 2 are now captured by “pure knowledge” and “understanding links”. Finally he identifies “knowledge of the curriculum”, which for David is what distinguishes between physics subject knowledge (which is captured by his “pure”, “applied” and “understanding links” knowledge) and “physics subject knowledge for a teacher”, which is “what the government requires me to teach”. When he talks about “curriculum” knowledge in more depth he initially includes knowledge of misconceptions as something unique to teachers, but then appears to change his mind, arguing that such knowledge would be obtained by anyone who has a good understanding of physics:

I think teachers need to know what the misconceptions are so they can firstly avoid reinforcing them as sometimes happens at school and definitely try to address them [...] I don’t think I would put that in my little bubble for teachers because I don’t think people, I don’t think physics knowledge requires you to know misconceptions. If you know the correct answer you don’t need to know the incorrect answer, in a way. [...] I think the idea that I’m trying to say is that if you had proper, the ability to understand physics and know physics you would know when what somebody else is saying, or what the media are saying or whatever, is a misconception. You would know that because you would know it to be wrong, by means of knowing what’s right. (David, interview 3)

There is no significant emphasis given to what could be described as pedagogical knowledge, in contrast to interview 2. However, at the end of the PGCE course David opts to add to his previous diagram (Fig. 22) rather than draw a new one. He adds “how to relate things to the student”, which re-establishes a place for the pedagogical knowledge he previously highlighted during interview 2. It could be that this is a result of the extensive school-based teaching experience he has gained during the PGCE course.

### ***C. Experiences of the SKE course***

During each interview David is positive about his experiences of the SKE course and compares it favourably to his experience of learning physics at school. He values the level of independence

expected of SKE students as it “gives you an opportunity to make what you will of it” and the variety of teaching approaches used by course tutors:

I never learned anything at school [...] the way I’m learning physics now. I’m just going about it in a totally different way and in a more independent way and in a more varied way (David, interview 3)

He describes being required to write a reflective log throughout the SKE course as useful for requiring him to pay attention to *how* he learns as well as *what* he learns, so that “you’re not just learning something and disconnecting yourself from it” (interview 3). David highlights approaches that require interaction with peers and tutors as “particularly useful”, such as the “group-based things” where he has to discuss and explain physics concepts with peers. He talks about his experience of “micro-teaching” during the course as something that “made me learn in a different way”. It is not just that he was required to present or share his understanding of physics ideas with peers that is significant; it is considering what others might already understand and, in particular, having to deal with their questions. David does not identify any aspects of the course that he describes as unsatisfactory, although he mentions the challenge of organising his working time at home when he was required to attend university sessions only two or three times a week. At the end of the PGCE course, having successfully achieved QTS, David reflects back on what he learned about himself as a result of the SKE course, and states:

you kind of learn through the SKE course that it’s possible to, as an adult, to be proactive and learn things in a different way, in an individual way (David, interview 4)

## 4.5 Charlie (cohort 2)

### ***A. Definitions/explanations of physics and the nature of science***

At the beginning of the SKE course Charlie has a concise view of what physics is:

I’d just boil it down to that: specifics and relationships of natural laws. That is physics knowledge, I guess...natural laws; it’s all of them. It’s our observations of what we see around us and of how nature behaves, the patterns by which it does (Charlie, interview 1)

He goes on to explain that physics consists of areas of knowledge, such as relativity and quantum mechanics, which result in “natural laws”, and then “the relationship between them really is physics” (Charlie, interview 1). By the time of interview 2 (several months into the SKE course) his explanation of physics has become:

The application of our studies of order to a perfectly ordered system (Charlie, interview 2)

When asked about the suitability of this explanation for children, Charlie recognises that it is too abstract, and states he would “have to say ‘studying nature, studying the universe’” (Charlie, interview 2). It is evident in both interviews that Charlie struggles to articulate his thoughts about defining physics until he starts to talk about the relationship between physics and the other sciences, about which he has a lot to say. What all sciences and scientists have in common is use of “scientific method”, but what distinguishes the sciences from each other is the physical scale of nature under investigation. At the start of the SKE course Charlie explains:

I don't think there are any differences between all of them, I think it's a difference of how far you want to zoom in I always think; like how microscopic do you want to go. I think if a student I'd just say how maths is just the study of order – how things are ordered – physics is just the application of that study of order to the universe, which is perfectly ordered. And then chemistry is just a study of physics for the elements. And biology is just, again, how the elements come together given enough time. (Charlie, interview 1)

He views physics as a subset of the broader scientific study of nature and he elaborates on this several months into the SKE course during interview 2:

I'm quite obsessed with the idea that the sciences are really just abstractions on each other, and maths is the study of order, it seems. And then physics just seems to be... like, we apply that study of order to the single ordered system that's perfectly ordered, the universe, and try and understand it. And without the advancements in maths you can't get the advancements in physics...chemistry is the abstraction of physics then. So there's these points where it becomes no longer useful, unless you're a computational chemist it's no longer useful to talk about if you're mixing sodium hydroxide and hydrochloric acid, you really don't want to be bringing up Schrodinger's time independent wave equation...like the way you'd use computer languages. So give them machine code and then you'll have C and then you'll have Java to

sit on top of C and then you'll have whatever thing you're using that sits on top of Java. It's just higher abstraction... (Charlie, interview 2)

Charlie recalls being unaware of distinctions between the sciences until he started secondary school, where he experienced the sciences as distinguished by their content:

...everything to do with cells becomes biology, everything to do with mixing stuff becomes chemistry, everything that's hard and cools, physics. [...] I think that's when they all separated out is when I was told in school that they were separate things... (Charlie, interview 2)

It was much later, towards the end of his BSc, that Charlie developed his current view of the relationship between the sciences, through living with flatmates who were studying different science subjects and through his wide reading of 'popular' science literature by authors such as Bill Bryson, Carl Sagan and Richard Feynman.

### ***B. Content and nature of physics subject knowledge***

At the start of the SKE course Charlie's position is that a teacher's physics subject knowledge is simply knowledge of physics. After several months Charlie now has a more complex model in mind that involves two distinct areas of knowledge (see Fig. 23). A teacher needs to know the same physics that the pupils are expected to understand and also have "beyond student level physics", where "you have to know...how the subject applies to the rest of the world" (Charlie, interview 2). This includes knowledge of potential careers and real-life examples of physics.

Charlie also explains that what makes teachers' knowledge distinctive is the ability to put together effective explanations based on understanding of the relationships between discrete factual ideas. He provides an example of a teacher trying to explain kinetic theory to students. Individual concepts such as momentum and energy are involved, but:

these relationships run through and you need... I think this is why we do concept maps. I can't stand them, but I think this is why we do them is to demonstrate that there's the specific little chunk and here's how it relates to all the other specific little chunks, so we can try and give you a nice picture. [...] and I think the relationships are... it's part of the subject knowledge, you need to know how these things

all interrelate, because if you don't then what have you got? You're a pub bore again, you've just got a load of facts that you can't do anything with (Charlie, interview 2)

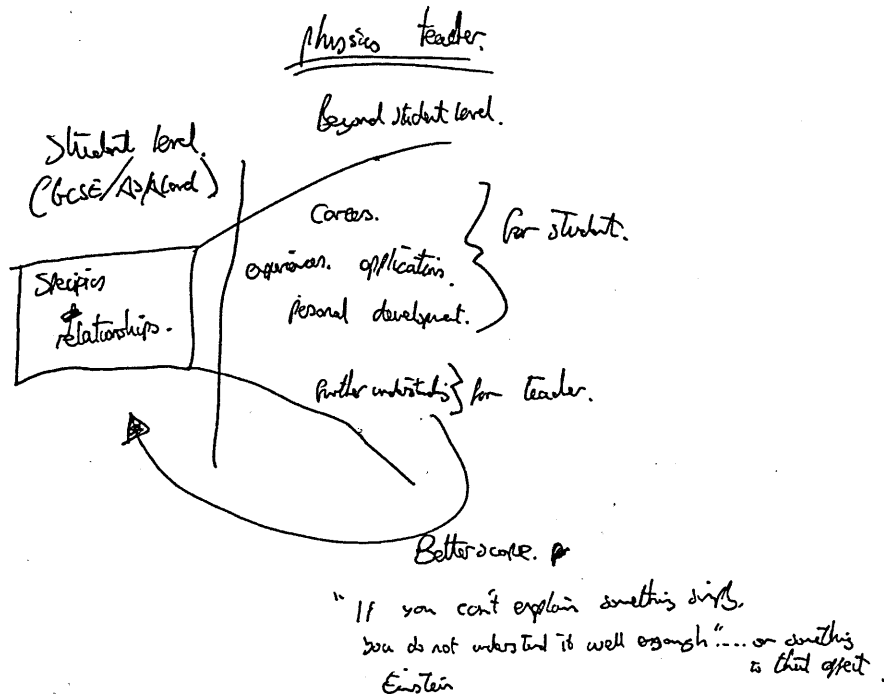


Fig. 23: Charlie's subject knowledge diagram for interview 2

### C. Experiences of the SKE course

Charlie's account of his experiences of the course during interview 2 is dominated by examples of developing insights into himself as a physics learner. He identifies the reflective logs as a "very useful" feature of the course:

I hate writing them, but when I sit down and write them things come to me that I hadn't thought of [...]

I'm asking myself, how would I teach it? What problems can I identify with? I'm not doing that in the classroom. And that's the bit I've enjoyed. [A course tutor] is always asking me for reflective logs. I don't write them. And it's weird, every time I sit down to write them, I enjoy writing them, but then I just can't stand writing them. It's weird to do; I hate writing about myself, but it's useful, it's very useful to me (Charlie, interview 2)

He also draws attention to the effect of questions asked by his peers during course sessions:

seeing other people interact with it [physics] and how other people do it and the questions other people ask that I couldn't have done with a textbook on my own. I think that's been valuable. Because I've seen people who... While I did A2 physics, there are people in my class who haven't done A2 physics and they ask questions. And, at the time, I don't really think about it, the questions that they asked, I just think, okay, that's that, okay, get that right in my head when I'm in there and that's what I'm doing. But then when I go away again, yeah, I think about the questions people asked... (Charlie, interview 2)

These, and other, examples suggest that the SKE course has stimulated Charlie to reflect on his course experiences as they relate to preparing to teach it. He talks at length about the teaching assistant placement, which although only two weeks long, has had a strong influence on his thinking. Prior to the placement Charlie felt confident about his subject knowledge, which he describes as “fluent”, but also aware of a need to test his confidence in a school environment. He talks for several minutes about realising during the placement the extent of the challenge of how to engage children with physics. He talks about “a crazy wobble” where he experienced a crisis of confidence about his ability to become a teacher. As a result of the school placement he now looks back at the SKE course and realises the value of being in a group of peers with the support of a ‘teacher’ and noticing what a teacher does to support learning:

There's a way that textbooks say things, and I've been learning out of textbooks, like, self-learning myself away from uni, and you have to sit there and if you don't get what it says on the paragraph, you have to sit there and go over it again in your head and again and again until you do get it. Whereas a teacher can come in and explain in a way that, if they're an attentive teacher... I realise that's such an important thing as well is to be attentive. [...] it's been nice to see that in action and to be there while somebody's explaining it. (Charlie, interview 2)

Charlie goes on to describe his anxiety about how well he will cope with the PGCE course and if he can learn to “communicate very well to a bunch of children”.

## **4.6 Jen (cohort 2)**

### ***A. Definitions/explanations of physics and the nature of science***

At the beginning of the SKE course Jen struggles initially to 'define' physics (Jen, interview 1) before deciding that for her physics is

a very big branch of science. A lot of physics can be used to explain how things work and why things are, so a lot of the time physics is something that will provide answers for you (Jen, interview 1)

When she explains this further she identifies the study of 'interaction' as one of the common features of all the sciences and what distinguishes them is the scale of the phenomena under investigation:

The chemistry shows how things interact, but at a really, really miniscule level I think, whereas physics shows how things interact but at a bigger level and on a bigger conceptual basis, biology shows how the world interrelates in terms of life [...] They all have the same rules (Jen, interview 1)

Several months into the SKE course, Jen places more emphasis on mathematics as a common denominator across the sciences, with 'interaction' featuring specifically in the context of physics:

Well there's a bigger emphasis on mathematical ability because a lot of physics, most parts of it, require being able to calculate and being able to use equations to explain different things. [...] physics is more to do with just how things interact, right down to like a sub particle level (Jen, interview 2)

During our discussions about the sciences in the first interview, Jen has a lot to say, unprompted, about chemistry in particular:

I find chemistry can explain things as well but it's very cold and it's very exact and it's all about numbers and letters, it's harder to use chemistry and apply it to a normal life for a normal person who doesn't know much about science; they'd probably find it harder to understand chemistry and to apply it because you need to know a good amount of scientific language to even understand a lot of chemistry [...] I think it's a foreign language and it can be quite cold and solitary (Jen, interview 1)

Jen goes on during this interview to describe chemistry as "cold", "hard" and "solitary", in contrast to biology, which is "warmer". I note that her description could be applied to any of the sciences and she is not specific about why she has such an apparently negative emotional reaction to chemistry.

**B. Content and nature of physics subject knowledge**

At the start of the SKE course Jen describes physics subject knowledge as

just basically being able to know everything to a standard that you can explain it and then to maybe know a little bit more to show why it's relevant and then also to know how it's applied (Jen, interview 1)

Jen uses the diagram task to construct her model of subject knowledge (see Fig. 24) through a process of thinking aloud, with very little prompting. She thinks a physics teacher needs to “know well basic science up to GCSE level” and “understand the curriculum for A level” for physics. Jen continues without prompting and identifies that a physics teacher also needs to have

extra information on more of the interesting areas that you can kind of use to show people how physics is beneficial and how it can be enjoyable as well. (Jen, interview 1)

which becomes knowledge of “specialised areas” on her diagram. Jen also identifies knowledge of how the curriculum will be assessed, with an emphasis on knowing about examinations “in order to feel like I was being relevant”. For Jen, knowledge of mathematics is included in subject knowledge, but only to be “confident enough” to be able to apply formulae “and to be able to do the questions that are in the curriculum and on the exam papers”. (Jen, interview 1)

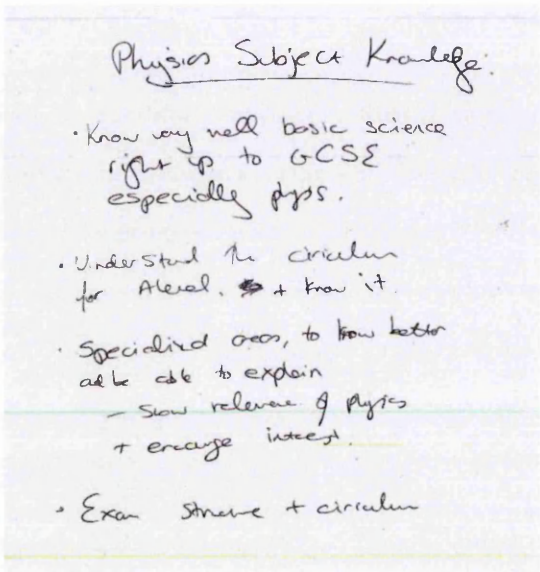


Fig. 24: Jen’s subject knowledge diagram for interview 1



Several months into the SKE course Jen's describes physics teachers needing "a good base understanding of the main topics" covered by the syllabus, which includes having "investigative skills" and "an ability in maths". Her descriptions are more oriented towards meeting the needs of the curriculum than they were at the start of the SKE course. Jen also includes in her responses descriptions of knowing when a teacher has sufficient subject knowledge:

I think you know enough if you're looking through the textbook and you recognise all the terms and the definitions that are there. (Jen, interview 2)

The textbook features more prominently now both as a source of subject knowledge and as a reference criterion for measuring competence in subject knowledge.

### ***C. Experiences of the SKE course***

Jen describes two aspects of the SKE course that she found most effective for her subject knowledge development. She first identifies "the practical element", especially when studying mechanics, as "useful", because she is aware of "a big emphasis on practical activity" in schools and that she herself does not "learn through practicals" effectively. Jen also identifies "micro-teaching" as there is a "completely different depth of knowledge required to teach". Jen thinks that the course was too long for her subject knowledge needs, pointing out that at times there were only course sessions on two and a half days per week. The course "could have all been done over maybe six weeks", which she thinks would have enabled her to enter the PGCE course directly, preceded by a short and intensive SKE course during the summer.

The SKE course experience has caused Jen to reflect on her reasons for becoming a teacher:

I think my motivations are still the same, because I wanted to be a teacher for a long time, but I suppose what's different is I have a different idea of what is entailed than what I did originally... (Jen, interview 2)

She also reflects on what kind of teacher she wants to become:

it's made me realise lots of different approaches you can have, but I'd like to be a teacher that makes the subject interesting and a teacher that points the kids in the right direction for the exams and helps them get through and be there. (Jen, interview 2)

Jen describes herself as wanting to be a science teacher, and not solely a physics teacher, as she is not convinced she is confident enough to teach it at A-level.

#### 4.7 Daniel (cohort 2)

##### *A. Definitions/explanations of physics and the nature of science*

Daniel's initial attempt to define physics, at the start of the SKE course, is:

It's how everything works, why the universe is that it is, why this does that, why that does this. It's just sort of why everything does everything; they try and explain why everything does everything (Daniel, interview 1)

When he is asked to do this again several months later he now describes physics in the context of the other sciences:

Physics is the senior science, that's the problem. That's the basis for it all; you know all this chemistry and biology nonsense. Physics is the senior one, so it probably sits, like it's at the heart of all the other sciences, physics leads to chemistry, chemistry leads to biology. Science, it's about understanding the universe we live in, trying to make sense of it. (Daniel, interview 2)

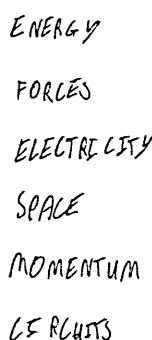
Daniel is being flippant when he says "that's the problem" and talks about how challenging he finds it to define physics concisely:

I don't really know what makes physics physics. Physics is, you know chemistry's about biology's about different things, plants and organisms, chemistry's about reactions you know on a large scale, small scale. Physics covers everything, it's the reaction of... , it's the universe, the physical world you know, what is around us. I don't know really, you ask some tough questions. Ask me in five years after I've been teaching it for a bit (Daniel, interview 2)

He discusses physics as a process of "coming up with ideas", testing them and then going "back to the drawing board" if they are shown to be incorrect. Daniel identifies that his thinking about physics as a subject has changed during the SKE course, from a view of it as a collection of "topics" to a view of physics as a "philosophy".

## ***B. Content and nature of physics subject knowledge***

Daniel attributes his view of physics subject knowledge to his experience of GCSE physics and the subject knowledge audit he completed when he started the SKE course. He lists a series of “topic headings” (Fig. 25).



ENERGY  
FORCES  
ELECTRICITY  
SPACE  
MOMENTUM  
CE RESULTS

Fig. 25: Daniel's subject knowledge diagram for interview 1

He elaborates on these “headings” by identifying sub-topics and concepts that a teacher needs to know. This is the extent of subject knowledge for Daniel. When interviewed several months later Daniel states that subject knowledge is “the knowledge you need to know for physics, all the topics, the practicals to be run”. He recalls the discussion of physics subject knowledge that took place during the focus group a few weeks previously with Charlie and Jen:

I could see Charlie and Jen putting down things like you know [...] time keeping and understanding and stuff like that. But, I don't consider that, that's not physics subject knowledge to me. That's part of being a good teacher, that's part of what you should be made up of but that's not subject knowledge. Subject knowledge to me is the subject knowledge, the topics you need to know to teach it. (Daniel, interview 2)

Daniel declines the offer to re-draw a subject knowledge diagram, stating that it would “say pretty much the same” as the one he drew during interview 1 (Fig. 25). Although his “attitude to teaching has maybe changed” he has not changed his “attitude to subject knowledge”. When he talks more about this he describes a friend who is teaching successfully outside of her subject

area and how her experience has shaped his view about the need for formal study of subject knowledge:

I honestly sort of think that having the degrees and the qualifications is great, but [...] if you, say, apprenticed under someone as a physics teacher for a couple of years, you could probably teach the physics class as well as anybody, you know, just learning what you need to know. You'll get asked questions over the years and you'll learn the answers. Degrees are good but that's not what makes a teacher. (Daniel, interview 2)

### ***C. Experiences of the SKE course***

Daniel has a lot to say about the SKE course. First of all, it provided an experience of learning physics that was more enjoyable than his experience of A-level in school, where:

it just seemed to be, I was just sitting in a maths class. Yes there was a nice level sort of explanation about why the ladder is leaning at that angle and you can calculate angles and heights and stuff and that was very nice but it was just a fancy way of wrapping up a maths question for me. But, this year I think it's been taught better because we have covered the maths but it hasn't felt like a maths class to me. We've still covered the same topics, we've still covered the same content but for whatever reason it felt like *physics* again and was good, enjoyable, just because we got so much crammed into one year with, you're not spending too long on any one topic [...] it just brought the appreciation of physics back. (Daniel, interview 2)

His account of his experience of the course is structured around how he feels about himself as a learner of physics, with improvement in his confidence and self-discipline through being part of a small group that sees itself as preparing to teach physics to children. The Teaching Assistant placement has provided opportunities to experience the physics misconceptions held by children (giving the example of children in one class struggling to grasp the distinction between *mass* and *weight*) and the extent to which they are addressed (or compounded) by different teachers' explanations. Daniel sees the placement as distinct from the SKE course itself, which is about his learning of physics, whereas the placement is about "how I would teach it". On the day of interview 2, Daniel had solo-taught an entire physics lesson in his placement school. As a result of

this experience he now no longer feels “a bit of a fraud” and feels able to describe himself as a physics teacher rather than a science teacher.

Overall, Daniel enjoyed the SKE course; especially the approaches to teaching modelled by tutors and the assessment task involving the production of a textbook chapter. He gives specific feedback about wanting some of the tasks set during the Science and the Public module to count towards the module mark. He also criticises how the content of the course was distributed over an academic year:

We could have just knocked this out if we actually just worked from nine to five for six weeks, eight weeks, you could have knocked the whole thing out, we'll have the same class time and for me certainly I was over here in [Albion], you know I don't know many people, didn't have a job, didn't particularly want to get a job this year although I didn't want a job this year because I liked the freedom that I could just nip home if I wanted to. So I spend sort of five days of my week sort of hanging about the flat and doing very little, I mean, and then assignments came in and I was like 'yes an assignment, something to do' (Daniel, interview 2)

He is looking forward to the PGCE course and wonders if the PGCE students with a physics background will be at a disadvantage compared to the SKE students, because they will struggle to “sort of dumb things down” to a level appropriate for children.

## **4.8 The focus groups**

The same question schedule was used for both focus groups (see Appendix B). In the transcript extracts shown below the symbol '[' is used to indicate where a speaker has been interrupted or the point where two or more speakers start talking.

### ***4.8.1 Focus group with cohort 1: Andy, Ben and Nick (see Fig. 10 on p.47)***

By the time of this focus group the participants have completed six months of the PGCE course. Andy, Ben and Nick start with commenting on each other's individual subject knowledge diagrams. There is some discussion about the extent to which knowledge of pedagogy is part of

physics subject knowledge and no resolution is reached. Their on-going experience of working with children during school-based placements is evident, where the discussion turns frequently to the realities of teaching physics in the classroom:

Nick        There's a classic case in there as well where kids always complain that they've been lied to when they progress through education, but I think you need to explain to them that it's just a more complex model, like the basic model was to aid their understanding when they were at that level; now they're a bit more advanced in terms of their abilities and their subject knowledge they can move on to a more complex model that would help explain different phenomena.

Andy        Yeah. So there's necessary lies at it were.

Ben        It's an approximation, that's what I told them, it's an approximation.

Int        Do you tell them that up front or do you wait until they say[

Ben        [Wait until they realise *(laughing)*[

Int        [and then you say "Well actually..."

(All overspeaking and laughing)

Nick        A few months ago I would have probably said that I would tell them up front, but now no *(laughing)*.

Int        So why do you say that now? What's changed?

Nick        You've just, you've just got to get through the day *(laughing)*.

The task requiring the group to agree on elements of subject knowledge and then to write them on individual post-it notes proceeds with Ben stating "we all agreed that a large portion of content is pure content, didn't we? So that will certainly be one of them". A consensus quickly emerges during discussion and five statements are produced (see Fig. 26). A discussion takes place about whether the participants see themselves as scientists. The full discussion is shown in Appendix I and will be the subject of analysis as post-EdD research. The participants then work together to rank the statements in order of significance (Fig. 26).

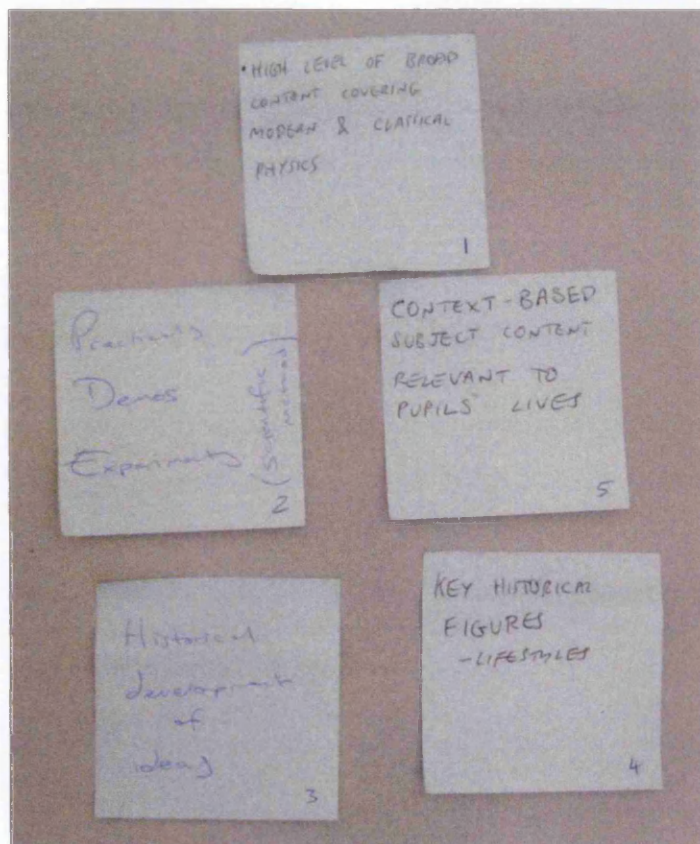


Fig. 26: Subject knowledge elements produced and ranked collaboratively by cohort 1

Statement 2 captures knowledge of pedagogical approaches, and includes knowing how to conduct practical activities with children and construct effective explanations. Later during the discussion, “scientific method” is added to reflect the need for teachers to not only know about ‘scientific method’, but also how to teach it to children. Statement 5 is seen by the group as important for making physics interesting to children by “being able to apply it to stuff that’s going on” (Ben). Having ranked the statements, the group discussed which were most important for a physics teacher as opposed to a physics scholar. The ensuing discussion is shown in its entirety in Appendix J. Initially there is discussion led by Ben about whether a physics teacher can have only knowledge corresponding to statement 1. The group agrees that statement 1 knowledge is important for being a physics teacher:

Ben        Because you can have these things [statements 2 and 5] but if you’ve got no subject knowledge [referring to statement 1] you’re not going to – if you don’t know any physics you’re not a physics teacher are you?

- Andy      No.
- Ben      Whereas you can still have all of this [*referring to statement 1*] and none of this interesting stuff [*referring to the other statements*], although my physics teachers, that's pretty much what they were, and would just write that [*referring to statement 1*] on a board for people to copy and you're still a physics teacher. Not a necessarily good one but you're still a physics teacher. Without that [*statement 1*] you're not a physics teacher you're just a guy...
- Nick      Talking rubbish (*laughing*)
- Ben      Banging stuff together.

When a hypothetical teacher is considered without statement 1 knowledge, but with knowledge of statements 2 and 5, then such a teacher “wouldn't be particularly effective” (Andy) and “like a supply teacher with some worksheets someone has left you” (Nick). There is agreement that knowledge of statements 3 and 4 are desirable, but not essential:

- Nick      I think three and four, the historical and development of ideas and including the bit about lifestyles and key figures, they're sort of niceties that bolt on to the bottom and feed back to what could make a good lesson, what could make a good teacher; they're not *essential*, but as you develop your teaching career your subject knowledge will improve in terms of your knowledge about historical figures and their impacts on science. And because of that knowledge increasing you'll be able to create more engaging lessons. So they do feed in to two and five but they're not essential.
- Ben      And they're strongly linked to the context sort of idea aren't they that they make it real, the concepts real. Like if some old guy is sat there in a lab doing this at some point because he didn't realise or because they had an inkling that it might be the case. I think it makes it a bit human as well.

When the group discusses the SKE course itself, there is consensus that the variety of resources and teaching approaches used is a good thing. There is discussion of the level of physics covered during the course, especially during the first few months. Ben says he would have “liked to have gone in at the deep end a bit more” leading Nick to claim that this “might scare off the sort of people who haven't done physics A-level”. Physics A-level is a prerequisite for the Albion Physics SKE course so Nick's comment perhaps points to an unvoiced conception of the ability or



experience of other members of the SKE course. Peer-teaching activities are discussed a lot as a positive experience during the course, but not without some criticisms of how it was implemented. Nick and Ben want more involvement of the course tutor during peer-teaching so they can “talk about things in depth more” (Nick) and “to have just validated everything that we’d done” (Ben). The group discusses the amount of unstructured time during the course. When asked about how they would redesign the course, there is some ambivalence about what they want and the role of unstructured time:

- Ben        Five days a week in a lecture theatre learning physics.
- Nick        More academically rigorous.
- Ben        A couple of weeks in the middle with some practical stuff.
- Andy        The spaces[ in the week
- Ben        [But they’re never going to pay for the lecturers time.
- Andy        The spaces in a week where we were supposed to be doing work and stuff like that they *definitely* helped [...]

The discussion above starts with each person making comments independently of what the others say. There is concern expressed during this exchange (and others) that different students perhaps need differing amounts of contact time. The participants then start to engage directly with each other’s comments and focus on the issue of contact time:

- Ben        I remember [the chemistry tutor] telling us it is a 40 hour course
- Andy        How many hours did you actually spend? I would’ve made up for it at the end but you know... Three days a week and there was a huge chunk of time where it was kind of... easy to just not do science.
- Ben        I rode my bike an awful lot and I climbed an awful lot (*laughs*)
- Andy        Instead of solidifying[ subject knowledge
- Ben        [Maybe that’s a maturity issue on our part, but yeah. (*laughs*)

I summarised some of the variety of lengths of SKE courses provided by universities across England and asked the group what they would prefer:

- Andy      I think the twelve months *[referring to the Albion SKE course, although the course was actually nine months long]* was definitely more – would definitely help us, but with more contact time I think
- Ben      Yeah. I don't think the microteaching stuff would've worked as well if we didn't have the time to prepare for it because we needed a few days at least to get your stuff together for that.
- Nick      I mean doing something over six months what are you going to do with yourself for the rest of the year? That's the more practical way of looking at it. [...]
- Andy      For me I wouldn't have too much of a problem with that [a six month SKE] but I think for other people it would be – for the people who are not as confident – it wouldn't help at all.
- Ben      I think I would've done less independent work if it had been crammed into six[ months.
- Andy      [Yeah
- Nick      [Yeah
- Ben      So I think it's better over twelve months in that respect.
- Andy      Yeah. I think the independent work is an important part of it I think.

Agreement emerges that they want the course length to remain unchanged. What is not discussed, and perhaps underlies these exchanges, is how the SKE students can be supported to use unstructured time in a way that feels satisfactory to them. The focus group concludes with some discussion of different possible course structures. Although there are differing views in the group about the balance between scheduled 'sessions' and independent work, all three participants value activities where they practice explaining or teaching physics to peers, and especially the value in having frequent involvement of a tutor in a setting where they can discuss physics *and* pedagogy with that tutor.

#### **4.8.2 Focus group with cohort 2: Charlie, Jen and Daniel (see Fig. 10 on p.47)**

Unlike cohort 1, the cohort 2 focus group participants have not yet completed the SKE course and have little school-based experience to inform their views. In the first section of the focus group, the views expressed by each participant about physics subject knowledge are consistent with the views they each expressed during the individual interview conducted soon after the start of the SKE course. When I ask the group about how they define the sciences, a consensus starts to emerge about different sciences studying nature at different scales. For example:

Charlie     You asked me actually in the first interview what biology was and I remember being stumped by it, I was just like ...

Jen         The study[ of life.

Daniel      [The study of living things.

Charlie     But it didn't occur to me that there was a study of living things. I was just like, it's just chemistry isn't it, that's sufficiently complex. I was just like, what is biology, I don't know, I didn't even study biology and I was on the bus and I was thinking, 'What is biology?' so I think that's useful, like for kids as well, so you can say biology is the study of living things.

Jen         It's a bigger scale. I mean chemistry is a medium scale and physics is a smaller scale I think, but with physics you're looking at things in more detail really.

Daniel      It's small but it's also big, because you're looking at galaxies and planets and ...

Jen         Yeah

The discussion then moves onto how the sciences are distinguished in practice at school compared to how they might be defined theoretically, prompted by a comment made by Daniel:

Daniel      If a kid asked me, I would just resort to going, 'This is what your syllabus is now, so you'll be doing this, this and this in that class and you'll be doing this and this in that class, there you go, go away'. [...] You'd ask them what they like in their science and then you say 'Oh there's biology in that, there's chemistry in that'.

- Charlie But that's your own perception of how the brain works and that's limited by what you know, so you're advising and they say, 'How the brain works' you might be inclined to say biology, whereas another teacher would say, 'Alright, well study computer science or chemistry'.
- Jen Mmmm. It would probably be chemistry in the end. But then you'd explain that to the students.

When the group start the task of assembling on post-it's the elements of subject knowledge (see Fig. 27), they start by naming five topics. After discussing additional topics they then consider that they could identify other aspects of subject knowledge:

- Charlie Well we can list like stuff ...
- Daniel Yeah, it will be just less on other topics.
- Jen Well, we're just listing topics.
- Daniel So maybe the topics is really just like a post-it note in itself so you need to know your stuff and then you need to know ...
- Jen You need to know a bit of maths, that's going to be ... Well you don't need to be brilliant at maths but you do need to know how to read graphs and [...] What else do we need? You need to read current affairs in physics, like be up-to-date and modern, well it's not modern physics anymore, it's current physics. Can I write that one? Current physics. So you need to, if some kid came up to ask you what the God Particle was, you'd have to be able to give an answer I suppose, and not a religious one.
- Daniel I think, like you need to know the current environment, everything that's going on.
- Jen Yeah. What I'd say for the physics industry, not necessarily the industry but like how it's ... it's to do with current physics, but like what it's used for, what do you say, engineering aspects, I suppose of physics.
- Daniel Current uses, you know, practical uses.
- Jen Yeah? The applications?
- Daniel Application.

Jen        That's the word. Applications of physics concepts. So there's something you're explaining, you can explain. Cool.

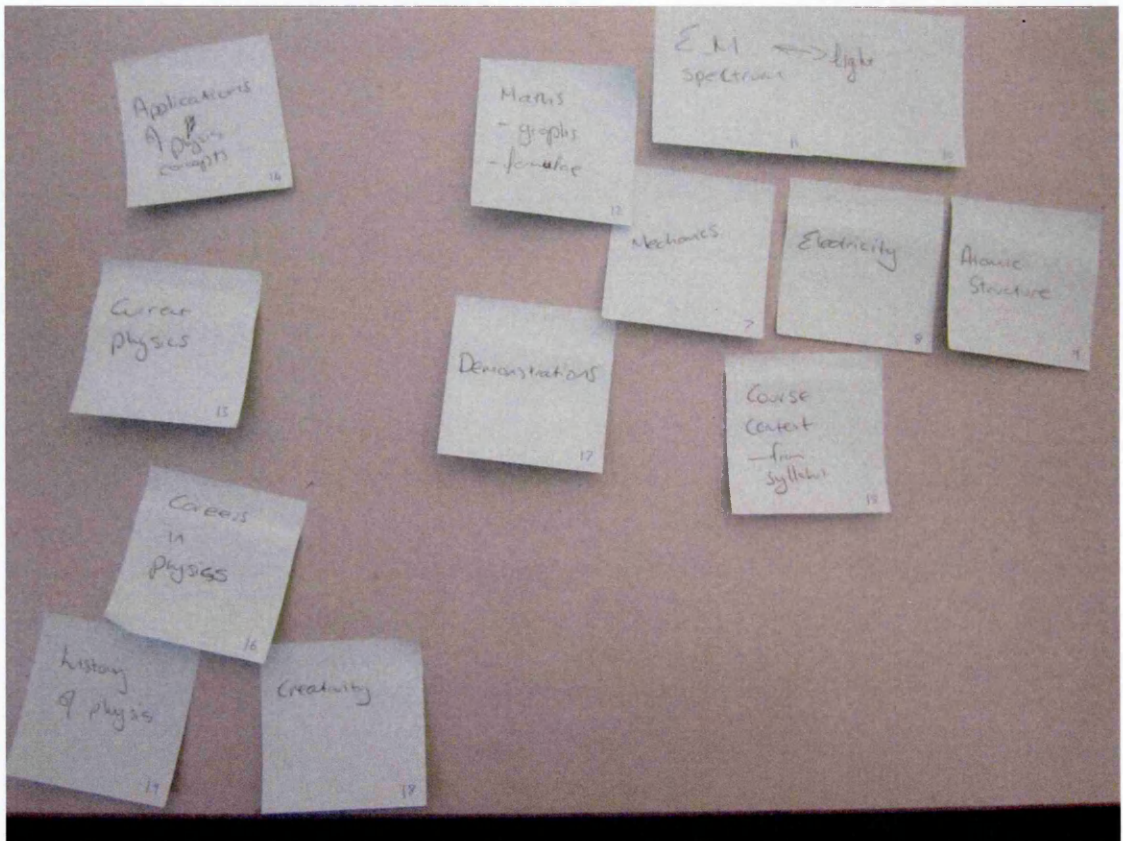


Fig. 27: Subject knowledge elements produced and ranked collaboratively by cohort 2

They proceed to divide their statements into two groups. The group on the right in Fig. 27 is summarised as “course content – from syllabus” (statement 15). Those on the left are summarised verbally as “context”. I ask if someone can be a physics teacher if they do not have the “context” knowledge. My question provokes a discussion, led by Charlie, about the place of pedagogical knowledge in the SKE course:

Daniel        Yes.

Charlie        This is my issue with the SKE. This is my main issue with the SKE. Like it seems we get all this [*“course content” knowledge*] with no allusion to any of this [*the “context” statements on the left of Fig. 27*].

Jen        And the thing is, a lot of us would have a good grasp of this in some ways anyway because we enjoy that and it's more to pursue a career in this direction, we want that.

Daniel     Actually, at the last rep meeting there was a point brought up about doing more micro-teaching and stuff like that and they [the course tutor team] actually did make the point that, you know, it is a subject knowledge course, it's not a pedagogy course. They do 'do' pedagogy but we shouldn't be expecting pedagogy on the course, it is a subject knowledge course.

Charlie    Okay, for example, we've just like outlined how subject knowledge like it's important we feel for a teacher to know the correct environment of physics, the applications of physics, concepts for a possible future. So like, we just said like that, subject knowledge, so we can't make that distinction and say. 'Don't worry about it, because, you know, it's just subject knowledge' and it's like well, no, because subject knowledge, we're going to need to know this stuff.

Jen        Yeah. And you see it like from the PGCE students this year, you see all the work they did and you we could have a better understanding of what's entailed in training as a teacher and, I know we do a reflective logs, but it would be good if we had a bit more practice at putting lessons together and therefore having to explain the subject knowledge and having to know it to a further degree.

They go on to discuss the difficulty that might be caused if the SKE course covered all the pedagogical content they think is covered during the PGCE. Jen comments that the "course content" knowledge could have been covered to her satisfaction in a much quicker time, leaving time for more exploration of pedagogical skills. She thinks now that "the subject knowledge is a smaller proportion of what a teacher should know" than she thought at the start of the SKE course. When the SKE course itself is discussed the group identify four types of experience that they each found to be significant for their learning. After talking briefly about the value of practical work during course sessions the group identify class discussions as important, especially what Jen describes as "completely unplanned discussions in class where we completely go off the main topic". The group identifies the value of these discussions as lying in their spontaneity, where they might originate with a comment or question from a peer, or from a tutor. The sharing of ideas seems to be significant as class members get to check their understanding of a concept during a discussion, whether they are participating or not:

Daniel     You get to share your ideas and listen to the ideas of other people, it's not just, you know, sitting there learning facts, you're seeing what other people think and they see what you think.

Jen        [It's more interactive. It wakes you up. [...]] There are some concepts that maybe you don't fully understand, like something that's said and then someone else will give an interpretation of that and then you understand it better. That's good.

The fourth significant experience is what the group call microteaching, which is described as "taking part in the lesson, you know, whether that's a starter activity or explaining something" (Daniel). The value of this activity seems to be that "you learn that you have to be clear and concise and put everything down for the kids" (Daniel), although there is a perception in the group that the chemistry SKE students get to do more of this than the physics SKE students do. The group discuss the possible merits of explaining concepts to the chemistry SKE students as an approach to be used during the physics SKE course; they identify a particular value in practising explanations with their peers within their own SKE group:

Jen        Well it would be easier to explain it to someone who doesn't know the topic because then you'd feel like you were an authority on the issue, whereas if you're explaining it to someone who knows it well, you're really conscious of the wording you're using.

Daniel     And explaining it back to the class, you're like, 'Am I getting this right?' you know, I'm pretty sure this is right but somebody could say I'm wrong and I'd be like, 'Oh right'.

Charlie    I like that anxiety. I like that in the preparation stages, so I'm sat there going to myself, 'Right, who's going to pull me apart?' and pulling it apart, it's like, 'I'm just waiting'.

When the discussion moves on to consider possible models of SKE course that rely on distance-learning approaches there is some agreement that physics content knowledge can be studied effectively alone and at home, but there is consensus that being able to interact with peers and tutors in real time, as concepts are encountered, is a valuable aspect of a SKE course:

Daniel     I like being *taught* it more than just self-learning. Just reading out of books and stuff like, you know, it's dull and boring whereas in a class it's a bit more interactive, getting taught it

by somebody who knows it rather than just sort of reading from a book, given that you could end up misinterpreting something and screw yourself over you know.

[...]

Charlie     I think recently I was trying to learn to programme code and there’s a lot of resources aren’t there, but sometimes I severely underestimate the value of interactive tuition when you’re learning something that you don’t already know.

Daniel     You can’t ask any questions to a You Tube video, so if there is something in the video and you’re like, ‘Well hang on, what’s that about?’ the video isn’t going to talk back and if the teachers don’t want to hear from you, how are you going to find out the answer?

There is also consensus that greater demand could be made of them during the SKE, in terms of study workload and number of assignments. Jen and Daniel appear to find it challenging to make effective use of the large amount of unstructured time during the course.

4.9 Comments

A summary overview of the extent to which key aspects of each participant’s views changed over time is shown below in Fig. 28. Comments are made about the participants’ conceptions of the subject of physics and of subject knowledge for teaching, and how, or if, they change over time.

	Conceptions of physics	Conceptions about subject knowledge for teaching	Comments
Nick	Initially (int1) physics consists of substantive content knowledge, organised into <i>classical</i> and <i>modern</i> physics, but these categories no longer feature by the end of the PGCE course. During the SKE course his view develops so that physics is “a body of knowledge and it’s also a way of thinking” (int3).	During the SKE course <i>broad brush knowledge</i> is used to refer to knowing how to engage children with physics examples that interest them, alongside knowledge of physics and how to help children to “discover physics for themselves” (int2). After the SKE course, factual content knowledge becomes the predominant feature.	Nick’s views about NoS are naïve (Faikhamta, 2013; Lederman et al., 2002), especially about scientific method as observation followed by theory generation (int2). His subject knowledge views suggest <i>discovery</i> and <i>inquiry</i> orientations to teaching (Magnusson et al., 1999) at the start of the SKE course, which widen to emphasise <i>didactic</i> or <i>academic rigor</i> during the PGCE course.



	Conceptions of physics	Conceptions about subject knowledge for teaching	Comments
Ben	There is an emphasis on physics as a body of factual knowledge ("fundamental physical laws of nature that govern how things work" int1) that persists across all interviews. By the start of the PGCE course there is more explicit reference to physics as a process, with particular reference to the role of "experiment and evidence and trying to use that to predict how things or objects will behave..." (int4).	During the SKE course, he moves from a simple body-of-knowledge-to-be-learned view (int1) to identification of different types of knowledge ( <i>textbook</i> and <i>pub quiz</i> ) coupled with knowledge of how to teach it and <i>fluency</i> as a criterion for having sufficient subject knowledge. By the end of the PGCE course the view has become more sophisticated with knowledge of children's misconceptions and how science relates to society now added. Fluency when explaining physics (an affective criterion for gaining sufficient subject knowledge) features from the end of the SKE course onwards.	Ben has naïve views about NoS (Faikhamta, 2013; Lederman et al., 2002) built around physics as a body of factual knowledge and, later in the SKE course, as an uncontested process of experimentation. His subject knowledge views suggest <i>academic rigor</i> , <i>didactic</i> and <i>activity-driven</i> orientations to teaching (Magnusson et al., 1999).
Andy	Emphasises physics as factual knowledge throughout all interviews and refers often to physics as the study of "interactions". There is some recognition of knowing physics as being able to use it to answer "why or what or how" questions. His views do not change during the SKE course.	Andy's views develop during the SKE course from being able to understand and communicate physics to others (start of the course) to an emphasis on knowledge of "science in the media" (end of the SKE course) and being able to relate physics to students' everyday lives.	Andy holds a narrow range of naïve views about NoS (Faikhamta, 2013; Lederman et al., 2002), especially in the category of <i>defining science</i> . His subject knowledge views are not well articulated and it is not clear what his orientations to teaching might be, which is consistent with the naiveté of his views about science, other than suggestions of a <i>didactic</i> orientation (Magnusson et al., 1999).
David	Physics as a process for studying and making laws about the universe is a feature throughout all interviews. Physics is about "how the world works" (int1) and is the "operating system for the universe" (int3).	Content knowledge of physics, divided into knowledge of facts and how to apply them to real situations, features throughout. By the end of the SKE course these are referred to as <i>pure knowledge</i> and <i>applied knowledge</i> . Knowing how to explain physics (in1) becomes knowledge of pedagogy and of misconceptions by int4.	David dwells on <i>laws and theories</i> and the <i>empirical evidence</i> aspects of NoS (Faikhamta, 2013; Lederman et al., 2002) more than most of the participants, although his views are more naïve than informed (he sees laws more as rules to be discovered than invented by people). An <i>inquiry</i> orientation to teaching appears to be more significant than others (Magnusson et al., 1999).
Charlie	No significant change. Physics has a body of knowledge, but is mostly about discovering the "relationships of natural laws" (int1). Different sciences study nature at different scales using scientific method.	His views develop from simple "knowledge of physics" (int1) to also knowing how to create explanations based on a deep understanding of discrete elements of factual knowledge and how they can be related to each other.	Charlie has a strong view of physics as part of a scientific endeavour to study "natural laws". His views about this are naïve in that he talks about laws as if they have an objective reality for scientists to 'discover' (Faikhamta, 2013; Lederman et al., 2002). There are perhaps suggestions of <i>academic rigor</i> and <i>didactic</i> orientations (Magnusson et al., 1999), although there is insufficient data about this.

	Conceptions of physics	Conceptions about subject knowledge for teaching	Comments
Jen	A view of physics as explaining “how things work and why things are” (int1) persists, with all of the sciences applying the “same rules” (int1) to achieve this. By interview 2, the relative importance of mathematics is used to discriminate physics from the other sciences.	Jen’s views develop from subject knowledge as knowing enough physics to be able to explain it to learners and how to apply it (int1), to using the curriculum and textbooks as reference points for knowing if you have sufficient physics knowledge to teach.	Naïve views (Faikhamta, 2013; Lederman et al., 2002) about <i>definition of physics</i> and the processes of science in establishing laws and theories that are created by people. Jen’s views suggest that science provides a reliable mechanism, through the application of consistent rules, for scientists to uncover answers to how the world works. Jen’s focus on the curriculum, and textbooks, as arbiters of necessary subject knowledge perhaps suggest orientations of presenting a body of knowledge ( <i>academic rigor</i> ) and transmitting the facts of science ( <i>didactic</i> ) (Magnusson et al., 1999).
Daniel	Initially Daniel describes physics as “how everything works” (int1), but during the SKE course he describes his view as changing from physics as a collection of topics to a philosophy for developing knowledge.	Daniel’s view does not change during the SKE course. For him, subject knowledge is “the topics you need to know to teach it” (int2) and knowing how to teach it is not part of subject knowledge.	NoS views are naïve (Faikhamta, 2013; Lederman et al., 2002) and lack breadth. He views subject knowledge as to be transmitted according to what is specified by a curriculum, suggesting a <i>didactic</i> orientation (Magnusson et al., 1999).

Fig. 28: Summary of participants’ views over time

The relative size of the sub-sections in the accounts from the individual interviews is a reflection of how much of each interview is spent discussing those areas. Some participants want to talk most of all about their experiences of learning physics prior to joining the SKE course, while others have a lot more to say about subject knowledge. The brevity of these accounts leads to obvious questions about what is left out and what I, as the interpreter of the participants’ stories, choose to emphasise. However, the accounts are intended to preserve faithfully what appears to be particular to each student and there are some observations that can be made when all of the participants are looked at together.

There are broad features in common across all of the students’ definitions of physics, such as a view of physics as a field of study that encompasses or underlies the other sciences. Physics is viewed as ‘fundamental’ in the sense of studying ‘everything around us’. Most of the participants appear to struggle to articulate a definition of physics, even after being asked to do so in every

interview. There is striking diversity of prior experiences of physics and views about subject knowledge. Some kind of knowledge of pedagogy features in most (but not all) of the participants' conceptions of what should be in a physics teacher's subject knowledge. The subject knowledge conceptions of some of the participants (for example, Ben and Andy) appear to change and develop throughout their ITE experience. Nick's conception appears to move full circle, starting and ending with a view of subject knowledge as primarily consisting of content knowledge of curriculum-defined topics. The subject knowledge diagrams themselves show a prevalence of spider diagrams, leading David to exclaim during one of the interviews that "I used to hate spider diagrams but years of education have trained me *{laughs}* [...] It's like a mental default". All participants report activities where they had to prepare and conduct mini-lessons of some sort to their peers as significant.

The focus groups provide a rich reservoir of data, full exploitation of which is beyond the scope of this research. During both focus groups, there is more agreement between participants than disagreement about all subjects discussed. This may be a consequence of the participants having formed largely-compatible views during the SKE course up to that point. However, both focus groups share more criticisms of the SKE course than each individual participant voices during the one-to-one interviews, such as the amount of unstructured time during the course and the academic demand of the course material. It may be that being part of a group enables some of them to feel more confident about voicing criticisms or concerns in the presence of their tutor, especially for cohort 1. The focus groups identify positive features of the SKE course which are consistent with those identified during the interviews, such as the perceived value of explaining-to-peers activities. As with the interviews, there is much discussion about the place of pedagogy in subject knowledge, with both groups constituting subject knowledge as including a fixed body of content knowledge.

In this chapter I have focussed on reporting the data and on emphasising the participants as individuals. In the next chapter I will consider what can be understood from analysing transversely across all of the participants.

## 5. Analysis: “I feel that it cements it in my own head”

In the preceding chapter I presented an account of each participant as an individual SKE student and some key points that emerged from looking at their interactions during a focus group. In this chapter I will analyse data collectively, i.e. by looking transversely ‘across’ all of the participants. First, I will report the main findings for Research Questions 1 and 2. I will then focus on two key concepts I have developed in response to Research Question 3, drawing on the idea of a community of practice (Wenger, 1998) as a theoretical lens through which to explain what the students found most significant about their experience of the SKE course.

### 5.1 What are physics SKE students’ conceptualisations of physics subject knowledge (RQ1) and how do they develop? (RQ2)

#### 5.1.1 Conceptions of physics

Despite differences in detail, the participants’ explanations of physics showed many features in common which were consistent during the SKE course, and PGCE course in the case of cohort 1, (see Fig. 28 on p.112). These can be summarised as *physics explains at a fundamental level how the world works in terms of the operation of laws; knowledge about these laws is gained by conducting experiments*, which is the one practical activity conducted by physicists that was mentioned frequently. Physics was talked about mainly as if it is a static body of objective knowledge that explains nature, and less so than as a process for constructing new explanations, i.e. their explanations focussed on substantive knowledge more than syntactical knowledge (Schwab, 1978). Although scientific method was mentioned, it was named as a characteristic that all of the sciences have in common rather than discussed in a detailed way as a description of how physicists ‘do’ physics, exemplified by comments made by Ben and Jen:

They all have the same basis, the three subjects are the same basis, they all have the same rules...so there is an awful lot in common. (Jen, interview 1)

I think the scientific methodology is common to all three. It has to be because they are all sciences. You know, the ideas of scientific rigour and objectivity and whatnot (Ben, interview 3)

All of the participants held naïve nature of science (NoS) views (Faikhamta, 2013; Lederman et al., 2002; Abd-El-Khalick and Lederman, 2000). As exemplified above, their views did not recognise the socio-cultural context in which science is conducted or the extent to which scientists interpret phenomena rather than discover an objective reality (Hodson, 1998; Duschl, 1990). The source for many of these naïve views appears to have been how the participants experienced physics at school, which seems to have been a major influence. Six of them described learning to recognise physics as a distinct subject through encountering it as a named subject for the first time on their school timetable, or through being told that what they were learning in a particular room in school was 'physics'. For example:

I think I probably became aware in secondary school, I imagine. I think once people start categorising them as separate, they appear separate. (Charlie, interview 3)

I was always aware of them. Like I don't know whether in first year I could've definitely gone "That's physics, that's chemistry", but certainly in third year we were split into the classes and that of course gives you a very good idea of what's physics, what's chemistry, by the name on the door. (Daniel, interview 1)

Dr whatisface and Miss whatsherface taught me in a chemistry lab and the timetable said chemistry and, you know, if I somebody showed me water and then they threw a piece of potassium into it and it started doing its thing I'd say 'this is chemistry', (a) because we did it in chemistry and (b) because it is to do with substances interacting... (David, interview 3)

Through that school experience they learned to recognise science as the discrete 'subjects' of biology, chemistry and physics through experiencing specified topic content in defined spaces with particular teachers. This experience appears to have reinforced naïve NoS views, as these same participants also referred to the different sciences as distinguished from each other by the idea of the *scale* of nature under investigation, typified by comments such as:

The differences, I think they are all different points on a spectrum really. I don't think there should be any real differences in how they think. I think they are each looking at different aspects of the same thing, on different scales perhaps. (Ben, interview 3)

I think it's a difference of how far you want to zoom in I always think; like how microscopic do you want to go [...] The difference between them is just how deep down you want to look. (Charlie, interview 1)

They recognised that there are differences between the sciences, so that they are constituted as discrete subjects at school, but these differences are not necessarily clear in the actual practice of scientists. It was noticeable that every participant struggled to define physics in a way that was satisfactory for them, even after being asked to describe physics in every interview, typified by David's comment:

You're studying the workings of things and...I don't know why this is such a difficult question *{laughter}*.

(David, interview 1)

Struggling to articulate explanations of physics does not seem to correlate with success at learning it. Although all found defining physics a challenging and uncomfortable experience, all passed the SKE course successfully, with Nick and Ben getting jobs as secondary school physics teachers before they had finished the PGCE course.

### **5.1.2 Conceptions of physics subject knowledge**

At first sight the participants' responses about subject knowledge, during the individual interviews and the focus groups, revealed diverse conceptualisations, although common features across all participants can be identified (see Fig. 28 on p.112). The participants used a range of different terms (for example "content" by Jen; "theory – core concepts" by Nick; "knowledge of the subject" by Andy; "factual knowledge" by Ben) in a way that is consistent with *Subject Matter Content Knowledge* (SMCK) (Shulman, 1986) or *subject knowledge* (Banks et al., 1999), which consisted of physics knowledge that can be codified and communicated to others. This knowledge was organised by the participants into "topics", which were recognisable from the school science

curriculum, such as *energy, forces and waves*. The school curriculum was present on some of the diagrams and was referred to during all of the interviews and focus groups, as a reference point for knowing what factual knowledge is needed by a teacher. In the language of Banks et al. (1999), what the participants were seeking to achieve during the SKE course was development of *school knowledge*, which is preceded by, and is transformed from, physics disciplinary knowledge (Deng, 2007; Stengel, 1997). This might also explain the tendency during the interviews for explanations to begin with, and revolve around, the subject of physics as structured and presented by the school curriculum. Given that none of the participants had been immersed in post-school study of physics, it is perhaps to be expected that their expectations of physics as a field of study were conflated with their experience of physics as presented in school.

Terms such as “deliver” (Andy), “pass the knowledge on” and “conferring that knowledge” (Ben) were typical of terms used by all participants that suggested a working epistemological model of subject knowledge as a body of ‘facts’ that can be communicated explicitly to learners, and common orientations to teaching of *academic rigor* and *didactic* (Magnusson et al., 1999). A view was also suggested of children having little or no prior access to an objective knowledge base that therefore must be ‘delivered’ by the teacher. Although this research was not designed explicitly to examine the participants’ orientations to teaching, it was noticeable that there was little if any suggestion of other orientations, such as *guided inquiry, conceptual change and project-based science* (Magnusson et al., 1999). There are suggestions in Nick’s data of an *inquiry* orientation and in Ben’s data, an *activity-driven* orientation, but additional data collection would be required to support any stronger conclusions.

Three participants identified types of factual knowledge that had meaning for them in how they thought about their subject knowledge development. Nick identified throughout all of the interviews a need to have “broad brush knowledge”, which is wide-ranging general knowledge of physics and how it can be made relevant with everyday examples, and a division between “classical” physics and “modern” physics. This division arose from the reading he did before starting the SKE course, which led to an appreciation of the paradigmatic shift that took place in

sciences with the development of quantum mechanics and Einstein's ideas about relativity.

Although Nick held on to this division throughout the SKE course, he did not articulate how these types of knowledge might differ in terms of implications for how they should be taught. It is noticeable that he no longer drew on these types of physics knowledge after completing the PGCE course. Perhaps the experience he had accrued during school-based placements had removed the value of thinking of subject knowledge in this way. Ben developed the ideas of "textbook" knowledge (factual knowledge as defined by a curriculum) and "pub quiz" knowledge, which is "general interesting facts or little quirks, and things like that...you wouldn't necessarily find in a textbook" (Ben, interview 2). Unlike Nick's "modern" and "classical" physics, these types of knowledge are not intrinsic to how physics itself can be divided. Rather, they related directly to how physics knowledge should be organised for teaching, and in particular, for providing criteria for knowing when Ben has sufficient subject knowledge to teach "fluently". These types of knowledge had currency for Ben at all stages of the SKE and PGCE courses. David, soon after the start of the PGCE course, drew on the ideas of "pure" knowledge, which appeared to be the content knowledge specified by the curriculum and consistent with Schwab's substantive knowledge (Schwab, 1978), and "applied" knowledge, which appeared to be knowledge of scientific method and approaches that could make the subject appealing to children, and incorporates syntactical knowledge (Schwab, 1978). These 'types' of knowledge are suggestive of attempts by the participants to consider the need to make the subject knowledge they are learning accessible to children, and could be thought of as akin to *pedagogical content knowledge* (PCK) (Grossman, 1990; Shulman, 1986) or *school knowledge* (Banks et al., 1999).

Knowledge of how to teach physics featured at different times for different participants. This is where the diagrams and the verbal responses tended to diverge in what they represented.

Knowledge of how to teach physics featured during all of the interviews. However, for some participants their view of whether this knowledge formed part of a teacher's physics subject knowledge or was a separate form of knowledge, changed during the SKE course. Nick, for example, highlighted during the second and third interviews the importance of knowing how to



use practical activities with children, but by the end of his PGCE course (interview 4) had decided that pedagogic knowledge did not belong under the umbrella of subject knowledge. As discussed in chapter 2, the term PCK is used by various authors to encompass a range of different aspects of subject knowledge (see Fig. 4 on p.34). Shulman's (1986) original idea was that PCK covers knowledge of 'representations' and knowledge of children's misconceptions. With this view of PCK, I suggest that PCK features for all of the participants in their views of what subject knowledge they should be learning.

While talking about their subject knowledge, the participants also talked about what it meant to them to have sufficient knowledge. Nobody appeared to measure sufficiency in terms of results on some kind of test that might be applied during the SKE course. For example, no participants, during the interviews or focus groups, referred to assessment results for any of the SKE course modules as a measure of their subject knowledge. Instead, affective criteria were referred to, such as "feeling confident" (Nick), not "having any fear of teaching a topic" (Jen) and feeling "confident enough...so it just rolls off your tongue" (Ben). These affective criteria were important for the participants and point to the need for SKE course tutors to pay attention to the interplay between SKE students' emotional experiences and their cognitive success at learning physics (Hodson, 1998).

Looked at overall, underneath the diverse ways of representing and talking about their subject knowledge shown here, there appears to be a common naïve view (Faikhamta, 2013; Lederman et al., 2002; Abd-El-Khalick and Lederman, 2000) of the need to learn a body of factual knowledge (which is talked about as if it is unchanging and universally agreed upon) and how to make this knowledge accessible to children. Models of subject knowledge that are predicated on the existence of a static body of objective content knowledge, such as Shulman (1986) and Banks et al. (1999), can be 'detected' in the participants' data, but it is not clear that doing so sheds useful light on the processes by which the SKE students developed their subject understanding as a result of the SKE course, and how this understanding developed over time. Attempting to 'see' in action the models proposed by Ellis (2007a) and Cochran et al. (1993) is more problematic. Both

models are based on the idea of ‘knowing how to teach physics’ as socially-situated, which arises from the dynamic interplay of bodies of knowledge (such as Cochran et al.’s knowledge of *subject matter* and of *pedagogy* (see Fig. 6 on p.38)) or from participating in the practice of the community of teachers (Ellis, 2007a). There are some instances of participants describing the effect, on their attitude to subject knowledge, of working with teachers in the school environment. For example, Ben recounts an experience of working with his mentor during one of his PGCE school-based placements and Nick describes a significant moment for him during the SKE course Teaching Assistant Experience:

Actually the guy who was doing the A-Level physics course at School1, like we both sat down and worked through stuff together, a lot of it. It was his first year running the programme and he was an electrical engineer originally, well by degree anyway, and so there was stuff there that he also hadn’t done before, so the curriculum had possibly changed since he did A-Level, as it has done for me, and, yeah, he just hadn’t come across it before. So we worked it out together and we got through it... (Ben, interview 4)

So if you just say to someone, “Oh Dave, what’s the formula for this?” Or “How do you explain blah blah blah?” Then they might look at you and think... They probably won’t because... I think when I was in the school last year, someone came in and they said something and I was thinking, and you’re a chemistry teacher and you don’t know that, I’m not even a chemist and I know that [laughter]. I can’t remember what it was but they said something and I was like... And loads of the science teachers were there going, “I don’t know either.” I was like, well, if they don’t know then that gives me a little bit of a light at the end of the tunnel. (Nick, interview 2)

The models described by Ellis (2007a) and Cochran et al. (1993) become more relevant when the participants report on their experiences of the SKE course and, in particular, when they explore their subject knowledge during activities that encourage interaction. This is where the data about what the students experienced as significant for their subject knowledge development is more useful and is discussed in section 5.2.

## 5.2 What do the students experience as significant for their subject knowledge development? (RQ3)

All of the participants without exception reported that their time on the SKE course had been positive, a finding consistent with satisfaction levels reported by physics SKE course students nationally (Gibson et al., 2013). Many of the Albion SKE students' comments were about how the participants felt about themselves and about physics as a result of the course:

I honestly enjoyed this year so I did, it gave me a new appreciation for physics I suppose or it just brought the appreciation of physics back. (Daniel, interview 2)

The individual accounts in chapter 4 illustrate the range of experiences each participant chose to highlight. For example, Ben consistently criticised the structure and purpose of the Science and the Public module as taking up valuable time that could have been devoted to exploration of more "theory". For Ben, the main value of the SKE course was having a dedicated tutor who taught timetabled sessions:

I think it was all really valuable. I think coming into education the second time round I lap it all up and I really appreciate having someone there whose job it is to just teach us stuff. (Ben, interview 3)

Nick discussed the SKE course as providing a "base level of knowledge" that he anticipated needing during the PGCE course, something which he felt the SKE course achieved successfully when he revisited this during interview 4 at the end of the PGCE course. David, Jen and Charlie all talked about the value of keeping a regular reflective log or journal. It appeared that the value of the log arose from its compulsory nature: the log forced these participants to take some time to think about their progress and how they were learning. All participants talked about the quantity and distribution of contact time with tutors as a source of some frustration. Some (Ben, Jen, Daniel) wanted the course to be shortened so that there would be more contact time during the week, but spread over a smaller number of weeks.

Looking across all participants revealed two key experiences of the course that were particularly significant: the role of *interaction* and the *implicit messages communicated by the nature of the SKE course itself*. I will discuss each of these in depth.

### 5.2.1 Interaction

It was important the group work we did, it was kind of not only understanding what we were learning but kind of helping others to understand it who may understand it themselves but obviously struggled in applying it to certain areas where I didn't (Andy, interview 3)

Most of the discussion during the individual interviews about experience of the SKE course highlighted the role of *interaction*. All participants talked about the value of being able to share and discuss their thoughts about physics with tutors and with peers. For example, group-based activities were highlighted as important for not only enabling the active participants in the activity to test and develop their understanding of a topic, but also for those who were less involved to compare their understanding with others, exemplified by comments such as:

Those sort of moments are good, you know just seeing how other people react to the same questions, "I never thought of it that way, that's good. I must remember that." (Daniel, interview 3)

Somebody's got one idea, somebody else has got some other idea and when they voice that out you can hear the different ways that people try to understand something. And I think it's difficult to imagine that, but once you're aware of it, it becomes a useful tool to know how they're trying to lay that understanding foundation down so that they can navigate it and not struggle (Charlie, interview 3)

The value of interaction appeared to manifest itself in different ways. The participants reported that they enjoyed being able to talk with each other about their developing understanding of physics. This enjoyment came from meeting a need for social connection during a course that involved 10 hours or less of session time per week, and for many of the participants, at a time when they were living in a city in which they had few if any social connections. At a deeper level, interaction appeared to serve several purposes. It enabled the participants to try out their understanding of physics concepts by sharing and receiving feedback. Discussion with peers took

place where understanding could be tested, applied, compared, evaluated and modified. The interaction could be as simple as spontaneous discussion during unstructured time during or outside of course sessions. During sessions, the interaction could arise from a question or discussion task set by a tutor, or as a result of a question raised by a student. A particular feature of interaction that appeared to have the most value for the participants is where they were required to explain physics concepts to each other. This could be during small-group work, where the students had to explain to a small group of peers a physics concept or the answer to a question set by a tutor. The participants reported that this kind of activity required them to not only ensure they understood the physics, but also to pay attention to *how* they arrived at that understanding, and the implications for how their reasoning should be presented to others.

Explaining to peers could be experienced as a one-way process, where there is an active explainer and passive receivers. When it became a two-way process, where the explainer and 'receivers' could interact by asking questions, much greater value was perceived by both. During the SKE course (and the PGCE course) such a two-way process was used during activities that were referred to as *peer-teaching* or *microteaching*. The precise definitions of these terms, and the distinctions between them, I will discuss later, but for now I will use the term *peer-teaching* to refer to structured activities where students, either individually or in groups, prepared and conducted mini 'lessons' to the remaining students in the class. The essential feature of this activity was that it involved some element of explaining physics concepts to peer-learners who in turn could ask questions of the peer-teachers during and after their explanations. As experienced by cohort 1, peer-teaching involved each group of 3 students working together to prepare and conduct a 45 minute 'lesson' on a physics concept that had not yet been covered during the SKE course. The aim was to give the students some experience of getting to grips with a topic in order to teach it to others, experience that would prepare them for such situations when they are teachers in schools. Cohort 2 experienced less of this type of structured activity during their SKE course, although both cohorts experienced peer-teaching during the PGCE course. During the

individual interviews and the focus groups peer-teaching activities were regarded as valuable experience for developing subject knowledge:

I like some of the things that were required of us, like the microteaching, where I think to learn about something and to teach it to someone else is the best way of learning about it yourself. So I think that was really useful and I had quite a few light bulb moments, as it were, last year. (Nick, interview 3)

I feel that it cements it in my own head and it gets a little better every time I explain it. (Andy, interview 1)

The participants were also not without their criticisms of the peer-teaching activities, although these criticisms were about how it was conducted rather than objecting to the activity itself. Ben's comment represents the main criticism from all participants of concern about getting the physics they were teaching 'correct', and wanting more intervention from a tutor in order to ensure this:

I think it's useful as long as you've explained the right thing; you're not giving each other false information. I think there's a danger of that if you're not supervised while you're doing it. Some people go off on tangents and stuff, but I think that's quite entertaining. (Ben, interview 2)

Analysis of the interview and focus group data suggests five key features of peer-teaching that made it significant, illustrated by comments from participants:

*i) Peer-teaching encouraged "deep learning" (Biggs and Tang, 1999, p.20) of the topic to be taught*

[T]here's a completely different depth of knowledge required to teach (Jen, interview 2)

Researching it or sort of preparing to do it, were good for subject knowledge stuff because you really root around trying to find different stuff out from various sources and you get it explained in different ways and sometimes slightly conflicting ideas so you would have to sieve it all out and figure out what's the right explanation of it and make a little mini lesson out of it, so that was good for subject knowledge specifically, that was very good. (Ben, interview 3)

The pressure of having to stand in front of peers and 'perform' as a teacher required the participants to explore and develop the depth of their understanding of a topic. Doing so

“solidifies it in your own mind really” (Nick, interview 2) and encouraged the peer-teachers to “learn in a different way... so first of all there was that taking ownership of it for yourself” (David, interview 3).

*ii) Peer-teaching required reflection on their own experience as a learner of the topic and what might work for a peer-learner*

I had to learn about going back to the misconceptions thing. I had to think ahead about what kind of questions people were going to ask and what kind of ideas they might already have and that’s something that you don’t think when you’re learning for yourself because you know what you know and you know what you think, and sometimes that might be a massive detriment because what you think might not even necessarily be right, you might be building on knowledge that isn’t even true, but when you’re thinking about what other people think as well it’s a whole new ball game (David, interview 3)

If I have produced something the day before, I’ve written it down on say a poster, and during that poster I’ve had to understand what I’m writing down so to prepare to explain it to somebody and then if they go, right well what does that mean and I’ve thought right that’s what I understand let’s see if you understand the same thing (Andy, interview 1)

I find that you’ve got to order your thoughts in your mind, as we did the other day in the lesson, you’ve got to think about this concept and you’ve got to think what small steps can I break it down into so it can best be understood by that person then it also has the added benefit of solidifying it in your own mind so everyone’s a winner basically. {laughter} (Nick, interview 1)

Teaching a group of peers encouraged the peer-teachers to reflect on their own experience of learning the content, and this provided a starting point for how they went about teaching it. This reflection on experience enabled the peer-teachers to develop awareness of a wider range of possible approaches to learning a concept, and to critique the perhaps unquestioned way in which they themselves learned it in the past.

*iii) Interacting with the peer-learners, and not just presenting to them, was an essential feature of the effectiveness of peer-teaching for developing subject understanding*

It's more the interaction with the other person that helps me more. The preparation is equally as important but when you're explaining to somebody it's kind of the interaction with that person that gives me a better understanding. So if I've explained something to somebody and they go I'm not too sure I'll be standing there thinking of it over in my head thinking "did I explain that right? Did I get it right?", and if I think "yes I got it right" then I need to explain it in a slightly different way and break it down even further. (Andy, interview 1)

I think it is how they respond. If you can look at someone as you're trying to explain to something to them and you can see they're just looking nonplussed or have a gormless expression all over their face you've got to stop and you've got to say, you know in your mind quickly you've got to think, right let's stop going down that road. Let's go back a couple of steps and let's make sure they understand that and if they don't then solidify that before you go on to the harder stuff. You've got to lay a foundation in a few sentences about the key concepts and judge quickly whether they are getting it or not. (Nick, interview 2)

What distinguished peer-teaching from delivering a presentation was the centrality of *interaction*. The aim was not to 'deliver' information, and to leave the audience to make of the presentation whatever they could. The aim was for the peer-learners to *learn*. This required the peer-teacher to consider carefully a pedagogic strategy and be sensitive to what was happening for the learners, and to respond accordingly. This real-time adaptation, while being the centre of attention and authority as the teacher, tested the depth of understanding the peer-teacher had of the content, and how this content connected with other ideas the learners were already familiar with. This process involved the peer-teacher having to ask and answer questions that perhaps could not be anticipated.



*iv) Some of the value of peer-teaching came from having to address unanticipated questions from peer-learners*

I much prefer to ask questions of people I'm trying to explain it to. I try to think back to the steps that I would have gone through to try and understand something and then try and repeat that through questioning people to see if that works in the same way and the difficulty comes when people don't perhaps follow the same steps that I would take to get there and then I get stumped so I need to approach it from a different angle. I guess the more fluent you get with the subject the more angles you will have to come in from. (Ben, interview 1)

Then when you're actually doing it... Because of the nature of what we were doing then it was a peer team, a microteaching session, somebody might ask a question and then while you're actually teaching it you think, oh yeah, I didn't think about it that way. And you might not be able to answer the question but somebody else within the peer learning group might be able to answer the question. So you're still learning about the dynamics of the classroom and how your knowledge could be increased in that situation while actually, well, you're meant to be teaching. (Nick, interview 3)

I thought I knew some stuff about electronics, somebody asked me a question and I didn't know the answer. So I kind of was like, that's a really good question and thought about it and we kind of worked it out together. I would have never have asked myself that question, so I wouldn't have figured that out on my own. I would have kind of like thought, you know, two years from now or next year I am teaching a class and a kid asks me that question I know the answer now because I never would have asked myself that question, that particular question, you know when you ask yourself questions you think about things so when somebody else spots something that you might not have spotted, it kind of completes your understanding of it. (David, interview 2)

The peer-teachers could find out how effective their explanations were and then questions from the peer-learners enabled them to modify their explanation in real time. It was the unanticipated nature of the questions raised that had the greatest value. No longer could delivery of a rehearsed and thought-through explanation be relied upon. Now the explainer had to engage with the learners and react accordingly. To do that, required the peer-teacher to have sufficient understanding of the concept being explained to enable real-time reviewing and restructuring of the explanatory strategy they were trying to follow.

v) *Some of the value of peer-teaching came from having to verbalise thinking*

I feel it kind of plays it back to me, what I've just said or what I've written. It plays it back to me into my own head and I start thinking it over, thinking "does that sound right, does that go with what I've learned?" (Andy, interview 1)

I think quite often you find "Yeah, I think I get that" and then – like for the first question today that you asked I think "Yeah, I know what physics is", but then if you try and articulate it you find you can end up struggling. So maybe I don't understand as well as I originally thought. (Ben, interview 2)

If you can hear the words coming out of your own mouth it gives you confidence that you know what you're talking about (Nick, interview 1)

Peer-teaching required the participants to verbalise their thoughts, i.e. they sometimes thought they knew and understood something, but verbalising it required them to think afresh the true extent of that understanding.

The significance of peer-teaching to the participants was an unexpected finding that emerged during analysis, and requires some further explanation. Peer-teaching approaches are used widely during ITE courses to support development of pedagogical skills and reflectivity (see for example, He and Yan, 2011; Zhang and Cheng, 2011; Fernández, 2010; Mergler and Tangen, 2010; L'Anson et al., 2003; Wilkinson, 1996). On the Albion SKE course the term *peer-teaching* is used interchangeably with the term *microteaching*. Microteaching came out of attempts at Stanford University in the early 1960s to develop ITE approaches that bridged a perceived gap between the pedagogical theories taught during university-based ITE lectures and the student teachers' ability to put the theories into action while teaching children (MacLeod, 1987). A simulated classroom would be set up in a university where student teachers would conduct short (typically 10-15 minutes) teaching episodes with a small group of school pupils (Hargie, 1977; McAleese, 1973). The teaching episode would be audio-visual or audio-only recorded, and the student teachers would watch the recording and use it to reflect on their teaching in conjunction with feedback from ITE tutors (feedback always seems to have emanated from the tutors and not from peers).

This kind of approach has been adapted in many ITE institutions where student teachers teach groups of peers rather than children, which meets a need for student teachers to have opportunities to develop several aspects of their knowledge simultaneously through the activity of teaching others (Nilsson, 2008; Magnusson et al., 1999; Cochran et al., 1993).

Little research has been done into the use of peer-teaching approaches for subject knowledge development. Development of subject knowledge involves student teachers identifying, confronting and reconstructing their own pre-conceptions (Hodson, 1998; Driver et al., 1994a and 1994b), i.e. the development of *metacognition* involving:

learners having an informed and self-directed approach to recognizing, evaluating and deciding whether or not to reconstruct. Hence metacognition and conceptual change are totally intertwined (Gunstone and Northfield, 1994, p.526)

Developing metacognition is most effectively achieved “in the context of learning tasks perceived by learners to be appropriate and valuable” (Gunstone and Northfield, 1994, p.526) and I suggest that this starts to explain why peer-teaching was so significant for those participants who experienced it. Peer-teaching enabled the participants to develop their metacognition about a physics concept or topic through trying out a range of pedagogical approaches and noticing their effect. As implemented on the Albion SKE, all students took it in turns to be peer-teachers and peer-learners, an approach termed *reciprocal peer learning* by Boud et al. (1999), where “students within a given cohort act as both teachers and learners” (p.414). Boud et al. (1999, p.415) propose four reasons why reciprocal peer learning in particular is effective for developing teacher knowledge:

- 1) Peer learning necessarily involves students working together and developing skills of collaboration. This gives them practice in planning and teamwork and involves them as part of a learning community in which they have a stake.
- 2) There are increased possibilities for students to engage in reflection and exploration of ideas when the authority of the teacher is not an immediate presence...

- 3) Students gain more practice in communicating in the subject area than is typically the case in learning activities when staff are present. They are able to articulate their understanding and have it critiqued by peers as well as learn from adopting the reciprocal role.
- 4) Peer learning involves a group of students taking collective responsibility for identifying their own learning needs and planning how these might be addressed. This is a vital learning-how-to-learn skill as well as providing practice for the kinds of interaction needed in employment...

The fourth reason is consistent with the idea of developing metacognition and is particularly important, as the students must be able to learn new subject knowledge in the demanding school-based environment. Considering this suite of reasons from the perspective of the SKE course as a community of practice at least partially explains why the participants experienced reciprocal peer learning approaches as significant for their subject knowledge development. As discussed in chapter 1, Wenger conceptualises learning as the negotiation of meaning through the convergence of participation and reification (Wenger, 1998), where participation is seen as the “mutual recognition” (p.56) of aspects of ourselves in others and reification is the ‘making real’ of an idea (such as the example of reifying Newton’s 2<sup>nd</sup> Law of Motion as  $F=ma$ ). One broader example of reification in an educational context is the creation of a curriculum. One property of a curriculum is commonly the “codification of knowledge into a reified subject matter” (Wenger, 1998, p.264), such as the specification of a SKE course syllabus. This reification adds a potential hurdle for the SKE students and introduces a “pedagogical cost” (p.264), which is making sense of the reification. Presenting to the students a series of items that have been reified by others runs the risk of communicating that the students’ task is simply to memorise these items. A key point in Wenger’s argument, that participation and reification constitute a duality, is illustrated by what happens when one is emphasized over the other (Wenger, 1998, p.65):

- 1) If participation prevails – if most of what matters is left unreified – then there may not be enough material to anchor the specificities of coordination and to uncover diverging assumptions. This is why lawyers always want everything in writing
- 2) If reification prevails – if everything is reified, but with little opportunity for shared experience and interactive negotiation – then there may not be enough overlap in participation to recover a

coordinated, relevant or generative meaning. This helps explain why putting everything in writing does not seem to solve all our problems

Point 2 offers an explanation for why reciprocal peer learning (Boud et al., 1999) appears to be so significant for the SKE students. It requires the students to negotiate for themselves the meaning of concepts encountered in the SKE curriculum. For the example of Newton's 2<sup>nd</sup> Law used above, being presented with  $F = ma$  (an experience of someone else's reification of a set of concepts) therefore requires "intense and specific participation" (Wenger, 1998, p.67) to make it meaningful, otherwise the formula is at risk of becoming simply another 'fact' to be memorised. I propose that this is why *interaction* appears to be central to the SKE students' experience. It points to the idea that peer-explaining approaches, whether simply one-way delivery of explanations or formalised reciprocal peer learning, are "epistemologically correct" (Wenger, 1998, p.101) for student teachers: they enable learning of the physics content through participation and reification, which is operationalised as learning of concepts through the simultaneous practice of pedagogy.

### ***5.2.2 The implicit messages communicated by the nature of the SKE course***

Many of the views about subject knowledge and how to teach it were informed by experiences during the SKE course which were not necessarily intended to influence the students' pedagogical knowledge. For example, when Nick, Andy and Charlie discussed their subject knowledge during the individual interviews they brought into their descriptions prior conceptions of physics, and supplemented them with experience of one particular SKE course module; called Science and the Public (see Fig. 1 on p.15). This module required the students to consider the relationship between science and wider society, and the purposes and moral implications of recent scientific developments, and it featured in their verbal descriptions of subject knowledge during interviews 1 and 2, such as:

Then on the right in terms of talking about teaching and wider concepts I think certainly, there's, obviously we've started that module [science and the public] so down here I've put physics in the world, the sub-headings I've got in here I'd probably put down a couple of bullet points and talk about media and politics because we've been learning about those concepts and how they interact with science so I'd probably add them to down there. (Nick, interview 1)

I am going to make reference to some of the stuff we have done in [science and the public]. I think that's the way science in schools is going. The way curriculums are going so that they are more relevant to pupils. (Nick, interview 2)

Given that some of the activities the students experienced during the Science and the Public module were about encouraging the students to reflect on how, or if, they could introduce the issues into schools, it is not surprising that the module featured in Nick's tentative view of subject knowledge. What is more interesting is the extent to which students' views were informed by SKE course experiences that *were not* intended primarily to inform the students' views of teaching, and were instead intended simply to inform the students' understanding of physics. For example,

Maybe there'd even be sort of sub-headings off practicals and er and er I'd be getting some sort of ideas about what I could do in the classroom in a few months time. **Certainly those ones we did with the Lenz's tube and the milk in the water.** (Nick, interview 1)

I think there should be more of a blending between the subjects really and I think that can be achieved by teaching the core concepts with things like examples of science in everyday life, **like the physics chapter that we are doing as one of our modules.** Instead of having a chemistry lesson, a biology lesson, a physics lesson, **you perhaps could do a massive project and then it's going to incorporate elements of physics, mathematics, biology, chemistry with emphasis on different ones at different times, but it's all about one topic** so they are learning about a massive subject and almost probably wouldn't realise what they are learning. (Nick, interview 2)

The sections highlighted in bold are examples of references to specific experiences on the SKE course. In the first example, Nick referred to two demonstrations used during the very first SKE session, where the students moved around a circus of activities which were intended to test their understanding of fundamental physics concepts. I, as course tutor, selected the circus activities to provoke thought about physics; there was no explicit intention on my part to use them to

consider pedagogical implications or to present them as activities that could be used with children. However, for Nick, when interviewed five weeks after experiencing these activities, they were not only memorable, but had also come to represent activities that could be used to support his future teaching. In the second example, Nick referred to a summative assessment task for one of the SKE course modules, where the students developed a physics textbook chapter, which approached school physics concepts in an everyday context. The aim of this assessment task was to require the students to develop their understanding of the relevant physics independently, but unlike in the previous example, this task did also have an explicit pedagogical focus. The aim of the course team was to encourage some pedagogical thinking about physics. Nick has taken this task as a potential model of cross-curricular teaching.

The above examples all refer to specific activities Nick experienced on the course. What is also apparent was the effect on his thinking of some of the approaches he experienced during the course, particularly in relation to the role of mathematics in school physics.

During this course I have felt that a **qualitative rather than a quantitative description of physics concepts** has been, you know, my eyes have been opened in terms of that's what you have to do to younger people, explaining things and then when there's no maths involved at all you have to really rely on your own descriptive language and analogies, etc. I can see that would be really useful as a concept.

(Nick, interview 2)

With maths, I think it's a really, really important tool in physics. I think it's all well and good to learn as much qualitative stuff as you can, but I think that's only useful up until a point. I think to utilise maths in physics content is essential really to understanding and using a lot of the concepts. For example, we did that work on the car engine last year and you could describe and explain how an engine works and so on, but if you don't know how much energy you're getting out of it versus how much energy you're putting in, i.e. how efficient it is, it's not going to be very useful to you in terms of designing something or engineering something. (Nick, interview 3)

In the first extract the course tutors' explicit emphasis on understanding of physics concepts through discussion, as opposed to memorisation of formulae and calculation of numerical results, had an impact on Nick's vision of how physics should be taught in school. By the time of interview

3 (soon after the start of the PGCE course), Nick had developed his view further and had placed more emphasis on use of mathematics. The “work on the car engine” he referred to took place *after* interview 2. His experience of studying physics in a context that appealed to his interests appeared to have consolidated his views, and had relegated the “qualitative stuff” in importance compared to use of maths, which is “essential really to understanding and using” concepts. Being able to use physics to come to conclusions, to be able to quantify, had become more “useful” for Nick than simply being able to “describe and explain”.

There are other examples in the data that suggest the influence of aspects of the SKE course on students’ metacognition, such as during a discussion with Ben during interview 2 when he reflected on his use of questions during peer-teaching and commented that “I know you do a lot of that in your teaching, you do a lot of questioning” (Ben, interview 2). David and Charlie described how they had started to pay attention to *how* tutors explained physics as well as *what* they were explaining:

When I was at school learning physics I was learning it in order to answer questions. For example you learn that velocity equals distance divided by time I was learning it so that when I got into the exam I could put 20 and 10 in and come out with 2, but when we’re doing it on the course, when you’re writing on the board  $v=s/t$  I find myself thinking about how [the tutor is] explaining it to us and the steps that lead you through to understanding it because I already just knew it in my head, you know  $v$  equals 17, and now I’m thinking about how I would explain it and not skipping steps in my head to just learning the end product, like how I to get to it. Learning the processes and the learning aspect of it as well. (David, interview 1)

Whereas a teacher can come in and explain in a way that, if they’re an attentive teacher... I realise now that’s such an important thing as well is to be attentive [...] What this has done for me, I think, has... it’s been a focus on the subject knowledge and watching a teacher teach it to a bunch of adults who want to learn this kind of thing. So behaviour management isn’t an issue. Classroom management isn’t an issue. All the other things that I can’t even conceive of that teachers have to put up with, they’re not an issue any more. It’s a focus study forming on how to deliver the subject knowledge and I think that’s been good. (Charlie, interview 2)



Although these are isolated examples, they suggest that experience of a wide range of aspects of the course influenced conceptions of what is important about subject knowledge, and how it could be taught. The participants *noticed* approaches and the *messages* communicated by the nature of the course itself; messages that in some cases were implicit and not the planned intention of the course tutors. The role of modelling by tutors has become a growing area of attention for researchers seeking to explore how to make ITE more effective. For example, Loughran and Berry (2005) and Korthagen et al. (2006) highlight the importance of a teacher educator acting as a 'role model'. This involves not just a tutor demonstrating and explaining 'how to teach', but also being aware that how they go about working with student teachers sends powerful messages about how to 'be' a teacher, and in the case of the Albion SKE course, what is important about physics subject knowledge. Lunenberg et al. (2006) develop the role of modelling further and distinguish between *implicit modelling*, where a tutor demonstrates a pedagogical approach through example, and *explicit modelling*, where the tutor explains *why* they are teaching in a particular way. Although most teacher educators do a great deal of implicit modelling of practice, its effectiveness is often limited because the student teachers "do not recognise those examples [and are often] totally unaware of the modelling aspect of their teacher educators' behaviour" (Lunenberg et al., 2006, p.590). Given that the participants report that they pick up on messages about teaching from the SKE course tutors, I suggest there is a great deal of implicit modelling going on. The background of the tutors as former school physics teachers perhaps makes this unsurprising. I propose that there may be a place for tutors to give more attention to explicit modelling, given the SKE students clear interest in learning about pedagogical approaches.

In chapter 1 I proposed that the SKE course can be seen as a site for students to cross boundaries between multiple communities of practice through brokering activities by course tutors. The nature and purpose of some of these activities was explicit, in that their purpose for preparing SKE students to eventually become teachers was made clear to the students. However, from analysing the participants' interview and focus group responses, and from reflecting on my insider

knowledge as a former SKE course tutor, I suggest that brokering takes place that is not explicit or even intentional on the part of the brokers. For example, David's comment above from interview 1, about noticing how a tutor has explained a formula, is indicative of such implicit brokering. In the example David refers to, I was the tutor teaching that session. The way I explained that formula was not intended to communicate pedagogical messages. This now seems naive to me. David noticed *how* I explained the formula as well as *what* I was explaining, and this stimulated him to think about pedagogical implications and the practice of physics teachers. The feature of the participants' experiences that I earlier identified as *effect of implicit messages* draws attention away from a possibly haphazard series of different messages picked up by different students at different times, and towards the central role of the tutor in brokering membership of a new range of communities of practice. Looked at in this way, I suggest that if the SKE course is about joining the communities of practice of physics and of physics teachers, then this requires brokers who themselves are, or have been, members of these communities.

### 5.3 Comments

In chapter 1 I proposed that the SKE course can be conceptualised in terms of a community of practice as defined by Wenger (1998). Wenger identified the defining elements of a community of practice as *mutual engagement* (p.73), *joint enterprise* (p.77) and a *shared repertoire* (p.82). Considering the SKE course as a community of practice had particular value when examining the participants' experiences of the SKE course. Mutual engagement was evident in the descriptions the participants provided of working together during the course. The participants brought to the course a diverse range of backgrounds and prior learning experiences of physics. What they all shared in common was a commitment, to various degrees, to learning physics for the shared goal of becoming physics teachers. Their mutual engagement in developing ways of working together, while encountering each other's prior experiences, was evident in various comments about noticing and reflecting on how their fellow students learned physics. The engagement in a joint enterprise and the development of a shared repertoire were particularly evident during reciprocal

peer learning activities. During these activities the participants engaged in “a collective process of negotiation” (p.77) as they established ways of being a teacher through responding to their peers as learners.

A deeper examination of the SKE course as a community of practice would require a more prolonged ethnographic approach of rich data collection, such as observational data while SKE students worked together during and outside of course sessions (Gray, 2014; Cohen et al., 2011), than was possible during this research. However, as discussed in section 5.2, this research makes two key contributions to the potential practice of SKE course designers, through viewing it as a community of practice in action. First of all, the SKE course can be seen as a site for brokering transitions (Wenger, 1998, p.105) between the communities of practice of students of physics subject knowledge and teachers of that subject. In the case of the Albion SKE course, this brokering is operationalised as modelling of practice by course tutors during taught sessions (Lunenberg et al., 2006; Loughran and Berry, 2005). Secondly, the course can be seen as a site for negotiating the meaning of physics subject knowledge through the interaction of participation and reification. In the case of the Albion course, this is operationalised most overtly and effectively during reciprocal peer learning activities (Boud et al., 1999). These two features (modelling and reciprocal peer learning) are only possible because of the construction of the Albion SKE course as a site for students and tutors to be physically present together on a regular basis so that interaction is possible.

The naïve (Faikhamta, 2013; Lederman et al., 2002) nature of science (NoS) views held by the participants, even after completing successfully the SKE course (and PGCE course for cohort 1), can be seen as an indication that the SKE course did not require the participants to reflect critically on how their experiences of learning physics at school have shaped their beliefs about science, and then to develop those NoS views sufficiently so they can make informed pedagogical choices. It has been highlighted by various authors (e.g. Friedrichsen et al., 2011; Abd-El-Khalick and Akerson, 2009; Abd-El-Khalick and Lederman, 2000; Jones et al., 1999; Magnusson et al., 1999) that teachers’, and student teachers’, beliefs about science need to be addressed explicitly

so that their effect on teachers' pedagogical approaches can be reflected on and developed purposively. One of the lessons that can be drawn from this research during the Albion SKE course is that the Science and the Public module did not meet this need, and did not appear to make this need explicit to the participants, evidenced by some of Ben's highly critical comments about the module.

In this chapter I have discussed what can be learned from analysing the participants as a group with a shared experience of the Albion SKE course. Through viewing the course as a community of practice, I have identified the significance of interaction for the students' learning and the role of the course tutor in brokering the students' transition into the practices of the communities of physics and physics teachers. In the next chapter, I discuss the conclusions and implications for practice, as well as my reflections on the conduct of the research.

## 6. Conclusions, implications and reflections

I have presented a small-scale study into the experiences and conceptualisations of subject knowledge held by students on a physics SKE course at a university in England. I used verbal and diagrammatic data from individual semi-structured interviews and focus groups in two ways. First of all, I have presented the participants as individual cases through which I could preserve the diversity of their self-constructed conceptualisations and stories of their experiences of the SKE course. Second, I have looked at what is suggested by considering the participants as a group of students with a shared experience of the Albion University SKE course. I will report in section 6.1 the main conclusions from this research and then discuss, in section 6.2, the implications of these conclusions for professional practice and current policy directions. In section 6.3 I will reflect on the conduct and design of the research, and the implications for my professional practice. Finally, in section 6.4, I will outline some recommended directions for further research.

### 6.1 Conclusions

#### 6.1.1 Research Questions 1 and 2

Examining what the participants say about physics shows that they see it as an area of science that provides fundamental explanations of phenomena observable in nature, such as the motion of objects and structure of matter, in terms of underlying concepts such as *forces*, *energy* and *waves*. The participants all identified biology, chemistry and physics as separate areas of science distinguished by distinct content. Their definitions of physics remained mostly stable throughout the SKE course. However, they did not highlight the tentative status of scientific claims or the role of scientists' personal beliefs and theories, and the priorities and prejudices of the wider society scientists are part of, in shaping how science is carried out. Such nature of science views can be described as naïve (Faikhamta, 2013; Lederman et al., 2002; Abd-el-Khalick and Lederman, 2000) and are often held by student science teachers. Instead, the participants placed more emphasis

on attempting to differentiate between the sciences in terms of the *scale* of nature under investigation. Although this concept of *scale* was often not well articulated and is easy to criticise, it highlights a key point that emerged from the research: during the SKE course (and the subsequent PGCE course for cohort 1) the participants were not required to articulate and justify a conception of physics. Although there was some exploration of what physics *is* during the first SKE course session, this exploration did not require the participants to make explicit their nature of science understanding and then develop a definition that they 'owned', and this might account for the difficulty many of them experienced when asked to define physics. Struggling to articulate a definition of physics did not seem to interfere with their ability to engage with the subject, although it is likely that their naïve (and unchallenged) views will limit their ability to develop their approach to teaching science when they start their teaching careers (Friedrichsen et al., 2011; Abd-El-Khalick and Akerson, 2009; Jones et al., 1999). There is a need for further study to explore in more detail not only how SKE course student teachers develop a personal view of physics, but how this view is operationalised in their subsequent approaches to teaching children during and beyond the PGCE course.

There is a striking diversity of conceptualisations about what constitutes subject knowledge for a physics teacher. How the participants talked about subject knowledge was sometimes idiosyncratic and difficult to reconcile with the apparently simple and concise pictures presented by the DfE and Albion University's literature, or with my own previously unquestioned views. Looking beyond the idiosyncrasies reveals that all participants identify components of factual content knowledge and knowledge of 'scientific method'. There is also a clear view that knowledge of how to teach physics to children is a vital part of the physics subject knowledge they expect to learn during the SKE course (which is consistent with what is reported by most SKE students nationally in Gibson et al. (2013)). Such views are consistent with subject knowledge models of a body of disciplinary knowledge, such as SMCK (Shulman, 1986) or 'subject knowledge' (Banks et al., 1999), and a distinct body of subject-specific pedagogical knowledge, such as PCK (Grossman, 1990; Shulman, 1986) or 'school knowledge' (Banks et al., 1999). These views are also

consistent with how SKE courses are described by policy makers, with reference to subject knowledge for teachers as something that can be acquired prior to learning how to teach it (Dept. for Education, 2014b). Whether physics pedagogical knowledge is seen by the participants as an integral part of physics subject knowledge, or as some kind of separate category of knowledge, is, I argue, less significant than the fact that they do not see the SKE course as a self-contained experience of learning physics. The participants have the end goal of becoming a physics teacher in sight from the beginning of the SKE course and see themselves as embarking on a two-year journey of transformation to achieve QTS. Perhaps because of this, there was no mention of defining success at learning physics in terms of test scores; although all recognised that they do require a correct understanding of physics. Instead, what appears to matter most to the participants is how they *feel* about their physics knowledge when they are called upon to use it to support someone else to learn. Affective success, such as feeling “confident”, “at ease” and “fluent” when explaining physics to others, is seen as at least as important as the cognitive success of having correct understanding. I suggest that not only is attempting to separate consideration of subject understanding from consideration of pedagogy not straightforward, but it is not even desirable or warranted (Ellis, 2007b; Segall, 2004).

### **6.1.2 Research Question 3**

Interaction with peers is a significant aspect of the SKE course experience. This interaction can be in a variety of forms, from discussing in pairs answers to physics questions to formal reciprocal peer learning (Boud et al., 1999) activities. Interaction can achieve affective goals, where students can develop feelings of confidence and ‘fluency’ about using and explaining physics, and cognitive goals, where students can evaluate and develop their conceptual understanding. Reciprocal peer learning approaches are particularly effective because they enable students to develop competence in physics *and* physics pedagogy. When examined from the point of view of the SKE course as constituting a community of practice (Wenger, 1998), interaction facilitates students to negotiate meaning through participation and reification of subject matter. Interactional activities,

such as reciprocal peer learning, enable the students to move beyond memorisation of factual knowledge to having to reify conceptual knowledge for themselves. In some sense, the physics concepts they need to learn exist on a social plane shared between their peers. By participating in reciprocal peer learning the students have to reframe these concepts so they 'own' or internalise them, a view of learning that is consistent with how some conceptualise children's learning of science concepts (see for example, Hodson, 1998).

On a more practical level, reciprocal peer learning activities also enable the students to try out and reflect on teaching approaches they can take with them into their school-based placements during the PGCE course. Approaches that facilitate interaction are effective and provide a powerful pedagogical asset that would be largely absent from a distance-learning on-line SKE approach. This is especially likely given the finding by Lock et al. (2011) that student teachers find peers to be valuable sources of subject knowledge support. There are two notes of caution to be sounded here. First of all, my research has not evaluated the link between how effective the participants report an experience to be and the effect on the participants' understanding of physics. Second, cohorts 1 and 2 experienced different amounts of peer-explaining activities (due to the involvement of different tutors) so no conclusions can be drawn here about appropriate quantity of such activities. These two considerations provide the starting point for further research.

The participants learn physics from teaching activities and course materials. However, the participants also learn how to explain physics and what is important about it from the practice of the course tutors, the design and use of materials, the content and structure of the SKE curriculum, etc. Along with formal peer-explaining activities, this 'hidden curriculum' plays a part in influencing the participants' beliefs about how physics should be taught. Given that the participants see themselves as student teachers and not simply as students of physics, the role of explicit modelling by tutors (Lunenberg et al., 2006; Loughran and Berry, 2005) may be a fruitful area for further research on the effectiveness of SKE courses.



### **6.1.3 Key messages**

In chapter 2 I proposed that models of subject knowledge can be placed on a spectrum of epistemological views (see Fig. 9 on p.43). When the participants talked about subject knowledge they did so in terms of a context-independent body of subject knowledge and separate knowledge of how to teach it. At first sight subject knowledge development during the SKE course is aligned with models of subject knowledge that lie towards the objectivist end of the spectrum, such as the SKE course as covering SMCK and the PGCE course covering PCK, in the language of Shulman (1986). However, when the participants' talked about their experiences of the SKE course what emerged as significant for their subject knowledge development was the role of reciprocal peer learning and the modelling of practice by course tutors, i.e. activities that required the SKE students to negotiate the meaning of subject knowledge through pedagogical acts. These two approaches are aligned with models of subject knowledge development that lie towards the other end of the spectrum, of learning of subject knowledge through engaging with the subject-specific practices of a community of physics education practitioners. Based on this research, there are two fundamental messages to be shared with the science education community. First, that subject knowledge development courses for teachers should be organised around the principle that subject knowledge is pedagogic in nature and is most effectively learned through pedagogic approaches, such as reciprocal peer learning. Second, this principle applies provided the SKE course (and I suggest all ITE courses in general) is designed to foster a community of practice, so that the course tutors consciously operationalise their role as brokers between communities, through such actions as explicit modelling of practice and challenging student teachers' conceptions about science.

## **6.2 Implications for practice and policy**

### ***6.2.1 Implications for SKE course practice***

SKE course tutors should:

- 1) Devote time throughout the course for students to make explicit, critique and develop their personal conceptions of science and physics. This will enable the students to have ownership of appropriate models of physics they can draw on to inform their teaching as they progress through their ITE course.
- 2) Use activities that require students to explain physics to peers, especially reciprocal peer learning approaches. Doing so enables students to develop subject understanding through practising pedagogy in a 'safe' setting. Such activities also enable students to develop confidence in their subject knowledge through addressing their peers' unanticipated questions.
- 3) Reflect on the messages about physics subject knowledge, and the practices of the community of physics teachers, they wish to communicate through the design and conduct of the course. This includes giving attention to how they model practice to students, and make the rationale for their practice explicit (see for example, Lunenberg et al., 2006; Loughran and Berry, 2005).

### ***6.2.2 Implications for ITE policy***

The current UK government has pursued an education policy in England of shifting provision and control of ITE into schools, with a consequent reduction in the involvement of universities. This is despite evidence from Ofsted that university-led ITE is generally of a higher quality than school-led ITE provision (Ofsted, 2011). The continued existence of SKE courses is in doubt with uncertainty over on-going funding arrangements. These policy and funding changes have threatened the existence of extended SKE courses, and have promoted the existence of shorter

and on-line SKE courses (for example, University of Sussex, 2014; Hibernia College, n.d.). The policy environment appears to be increasingly unfriendly to the provision of ITE subject knowledge courses that can draw on the strengths of peer-peer interaction and modelling of practice by experienced teacher educators. Student teachers value SKE provision conducted by teacher educators in a university more than provision from academics in university physics departments (Lock et al., 2011). ITE policy should:

- 4) Nurture pre-service subject knowledge enhancement courses that provide a setting and sufficient time for sustained interaction so students can explore their subject understanding and develop confidence in applying it, without the multiple demands that are experienced in a school-based setting.
- 5) Ensure SKE courses are designed and led by experienced teacher educators who can draw on their subject pedagogical expertise to model effective practice, and prepare SKE students to apply their subject knowledge effectively to support children's learning.

## **6.3 Reflections**

The willingness and commitment of my participants should be acknowledged. The participants were open and forthcoming about their experiences and willing to engage with questions that were not always easy or comfortable to answer.

### ***6.3.1 Research design and implementation***

Conducting and analysing so many research interviews while also in full-time employment was challenging. However, conducting multiple interviews with the same participants revealed developments in the participants' thinking, and I was able to revisit items of interest from previous interviews. The multiple interviews also enabled the establishment of trust and a productive relationship with each participant, as well as developing my practice as a researcher. As a novice researcher, during the interviews I noticed sometimes a difference between what I

thought my questions would elicit and how the students interpreted them. Often the open nature of the questions had the effect I wanted of encouraging the participants to 'think aloud'; at other times the questions caused confusion and I had to re-phrase them into a more closed form. Sometimes participants provided detailed answers to subtly different questions from the ones I thought I was asking.

The subject knowledge diagrams proved to be a useful tool for structuring the individual interviews and for providing a scaffold for the participants to construct their ideas. The use of post-its during the focus groups had a similar positive effect of providing an artefact around which the group participants organised their discussions. I intend to explore the use of such graphical tools in future research.

The reliance on individual interviews as the primary data collection approach perhaps did limit the insights that could be developed. I have justified use of this approach in chapter 3 and I maintain that much of interest and value was collected during the interviews. Time and logistical constraints influenced my data collection design, but I also recognise that boundaries have to be placed around any research and methodological choices are driven by pragmatism as much as research ideology. I would now try and make greater use of focus groups as a tool. Time and space has been a constraining factor in their use during this project. I am keen to explore further the potential for making use of the interaction of a focus group (Belzile and Öberg, 2012; Wilkinson, 2011) to explore how participants conceive of subject knowledge.

There are two further changes I would make. First, I would also collect data from physics-background PGCE students about their conceptualisations of subject knowledge. This would provide some additional context in which to place SKE subject knowledge diagrams, at the risk of diluting my original aim of exploring the SKE students experiences rather than conducting a comparative study. Second, I would consider making greater use of a participant validation approach, where I would share with each participant the individual accounts I created for chapter 4. This would enable additional data to be collected in the form of the participants' interpretations and corrections of my accounts.

### **6.3.2 My positionality**

I discussed in chapter 3 issues of my status as an insider-researcher (Sikes and Potts, 2008). One of the challenges I experienced during this research was dealing with the change in my status during data collection from being a course tutor researching his own students (cohort 1), to a former course tutor researching some former students (cohort 1 during their PGCE year) and some 'new' students (cohort 2). This change was unavoidable as a result of me leaving Albion University. In some respects, the change was positive, in that it addressed a tension I experienced about researching some of my own students who I had responsibility for as a tutor. I noticed that I felt more at ease with continuing to collect data from cohort 1 during their PGCE year, when I was no longer based in Albion University or involved with the SKE course. My former-insider knowledge proved invaluable in making sense of many of the participants' responses. With cohort 2, recruitment of participants was more problematic than with cohort 1 because I had very little opportunity to build a relationship with that group of SKE students so that they might feel 'safe' with volunteering for this research. I tried to pay close attention during data collection and analysis to any signs that my status influenced the participants' responses or behaviour. I recognise that it is unrealistic to conclude that my insider status had no influence on the participants. I have already commented, for example, that the participants appeared to be more willing to verbalise criticisms of the SKE course to me while in the relative safety of the focus groups than they were individually. However, some unprompted criticisms were voiced during the individual interviews, and my impression was that all of the participants felt able to share their thoughts about the course and about peers (evidenced by participants' comments about relationships and experiences with peers and other tutors, which I have kept confidential). I am wary of overstating the positionality problem to the extent of concluding that the research should not have been carried out. I contend that some useful and valuable insights have been generated, and I am mindful of the warning from Miles and Huberman (1994) not to "inflate the potential problem; you are not really such an important presence in the lives of these people" (p.266). Clearly, this research is open to criticism because of my place in it, but I am confident that I took

as much account of this as was reasonably possible during data collection and analysis, while also making effective use of my insider knowledge of the research setting.

### ***6.3.3 Implications for my practice***

Conducting this research has raised my awareness and understanding of several aspects of my practice. During my work with PGCE students I had always seen part of my role as to model pedagogical practice to student teachers. One of the lessons for me from this research is the importance of being aware of the messages I communicate about pedagogical practice and the subject of physics to all ITE students. When working with SKE students I need to pay attention to their prior experiences as learners, and create time and opportunity for them to make explicit their personal learning histories of physics how those histories might inform their practice as physics teachers. In my role as a teacher educator I am continuing to explore the implications of viewing the students as a community of practice and in particular, my role as a broker of connections between the communities of pre-service and in-service teachers. As a result of this research, I have already incorporated reciprocal peer learning into my work with ITE students. In my other role as a novice educational researcher I am developing my membership of the community of practice of education academics as I negotiate new meanings about educational knowledge. I have learned the value of exploring in depth individuals' experiences of an educational setting and some of the pros and cons of a wide range of research methods.

### **6.4 Further areas for research**

There are three main avenues of further research I recommend:

- 1) To follow the original participants from this research as they progress in their teaching careers. What happens over time to SKE students and how their practice develops, especially in the subject of physics, has not been researched. I plan to use data from this research to

form the starting point for a long-term longitudinal study over at least the next five years (this type of research is called for in SCORE (2011, recommendation 14)). Research shows that about 40% of secondary teachers leave the profession within the first five years of joining it (Smithers and Robinson, 2008). There is potentially much to learn about the experiences of physics teachers, and especially ex-SKE physics teachers, during the first few years of their practice. This could help to provide insights into the significance of a teacher's Bachelor degree background to the development of competence and confidence as a teacher, as well as to learn more about the strategies ex-SKE-route teachers use to develop their subject knowledge.

- 2) To explore the relationship between the experiences and conceptualisations I have reported here and the quality of the students' understanding of physics concepts. This could help to develop understanding about how the ability of SKE students to negotiate their way successfully through the ITE experience depends on their competence and confidence with learning and applying physics.
- 3) The use of observational approaches during SKE courses to study what happens for students while they are engaged in the day to day experience of the course. This might shed light on the nature of participation between peers and with tutors, beyond what students might self-report to a researcher.

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## 8. Appendices

### A. Glossary

**A-level:** officially known as the General Certificate of Education Advanced Level, A-levels are qualifications offered by a range of Examinations Boards to schools in the UK and in Commonwealth countries. A-level courses typically require two years of study (usually Years 12 and 13 in England). The first year of study is assessed and leads to the award of an AS-level qualification. In most schools children study typically five subjects at AS-level, but some study fewer and a small number study six. Pupils then continue studying typically three of their AS-level subjects for an additional year, leading to assessment for a full A-level qualification.

**Academy schools:** state-funded schools in England, which are funded directly by central government (and sometimes also partially by a private sponsor) and are outside of local authority control. Academies are free to set their own teachers' pay and conditions, and are not bound by the National Curriculum.

**DfE:** the government Department for Education, which is responsible for the education system in England

**Free schools:** independent schools in England that can be set up by a sponsor, such as a business, an existing academy school or a group of parents, with state funding. Free schools, like academies, can set their own teachers' pay and conditions and set their own curriculum.

**GCSE:** General Certificate of Secondary Education. A qualification taken by many pupils in England, Wales and Northern Ireland at the age of 16. GCSEs can be taken in a wide range of subjects and are usually studied over the two years of Key Stage 4 in England. In some schools in England GCSE studies in certain subjects commence during Year 9, or are completed in one year of study during Key Stage 4, to enable pupils to gain additional GCSE qualifications. GCSEs are also offered in some countries which are former British colonies, and there is an international version, the IGCSE, which is offered by English examinations boards around the world.

**ITE:** Initial Teacher Education. Refers to pre-service teacher preparation.

**ITT:** Initial Teacher Training. Refers to pre-service teacher preparation.

**Key Stage (often abbreviated to KS):** used in England, Wales and Northern Ireland to denote the expected level of knowledge and understanding to be achieved by pupils in a range of school subjects at fixed points during primary (covering KS1 and KS2) and secondary (covering KS3 and KS4) schooling. In England, Key Stage 3 covers Years 7-9 (ages 11 to 14) and Key Stage 4 covers Years 10-11 (ages 14 to 16).

**PGCE:** Post-Graduate Certificate in Education. A Master's-level course run mostly by universities in England, Wales and Northern Ireland. A PGCE is typically completed over one academic year (although part-time versions exist which take longer to complete) and prepares students with a Bachelor degree to become qualified teachers. Most PGCE courses prepare students to become secondary school teachers of a particular subject, although there are also PGCE courses that prepare primary school teachers. Some universities also offer a Professional Graduate Certificate in Education, a non-Master's-level equivalent.

**QTS:** Qualified Teacher Status. The teaching qualification required to be employed as a qualified school teacher in a state school in England and Wales. Academy schools are allowed to employ teachers without QTS if they are deemed to be suitable experienced.

**Sixth form:** a term used in England, Wales and Northern Ireland to represent the 'Key Stage' that would cover pupils between the ages of 16-18 (Years 12 and 13 in England), when A-levels and other post-16 courses are studied.

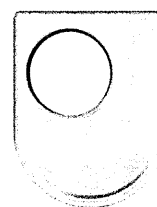
**SKE:** Subject Knowledge Enhancement. A term usually used to denote a pre-ITE course for enhancing a student teacher's subject knowledge.

**Year or Year group:** refers to one academic year of study. In England, primary schooling typically covers Year 1 to Year 6, with secondary school commencing with Year 7 and ending with Year 11, or Year 13 if the school has a Sixth Form

B. Interview and focus group plans

Individual Interview Question Schedule			
	<i>What am I trying to find out? About which RQ?</i>	Question content	Possible prompt(s)
1	<i>Some key biographical data</i>	Ask about educational background and their ‘educational story’ leading up to becoming a student teacher. Likely to be interview 1 only, but may revisit in later interviews.	Why have you chosen to become a physics teacher? Can you tell me about a positive experience you have had of learning physics?
2	<i>RQ1 &amp; 2 The student’s working mental model of physics. To what extent the student sees a difference between learning physics and learning physics for school teaching.</i>	Exploration of the student’s working mental model of the nature of physics through asking the student to create a diagram that represents physics subject knowledge and then talking about its features.	What might be unique for physics teachers? What was the first thing you thought about or drew? How might developing physics subject knowledge be different from developing physics subject knowledge to become a physics teacher?
3	<i>RQ1 &amp; 2 The student’s working mental model of physics.</i>	How they would define physics. What is distinctive about physics compared to the other sciences and what does it have in common with them.	How would you explain to a pupil/parent/family member what physics is? What would you tell the pupil they are going to learn if they study physics? What is the relationship between maths and physics, and maths and the other sciences?
4	<i>RQ3 What the participants think about the SKE course. What they think has been useful for their subject knowledge development overall. How has the SKE course affected their view of themselves as physics learners.</i>	Some of the significant experiences for the student’s development of physics subject knowledge during the ITE course so far.	Tell me about an experience during the course so far that you think moved your physics understanding forward. If you were going to redesign the SKE course, what changes would you make? What would you keep the same or do more/less of? What effect does having to explain a concept to others have on learning it yourself? What have you learned about yourself as a learner of physics since the course started?

Focus Group Plan				
1) what are physics SKE students' conceptualisations of physics subject knowledge? 2) how do these conceptualisations develop during ITE? 3) what do the students experience as significant for their subject knowledge development?				
Task	R. Q.	Activity/question or prompts	Thoughts	Time
		<ul style="list-style-type: none"> <li>• <i>Arrange room so I am seated as a group member. Check the acoustics. Place stopclock in my view.</i></li> <li>• Welcome and check-in about school placement experience so far</li> <li>• Explain how the focus group is going to work and that this is not a 'group interview', reminder of confidentiality and ground rules (only one person talking at a time; no 'side discussions'; mobiles off)</li> <li>• <b>[Start stopclock]</b> Start by getting each person to go round and identify themselves (perhaps share something about the last physics topic they taught)</li> </ul>	Try to avoid pre-empting later questions	5
A	1	Ask participants to work individually and without conferring to construct a SK diagram. Tell students to be prepared to share their diagrams.		10
B	1 2	Gallery the diagrams and ask for comments. Do not let students take it in turns to 'present' as this might stifle discussion.  Prompt for discussion about how their views might have changed since the start of the SKE course.	Think about prompts that are not directive e.g. 'XX you look as if you are disagreeing with YY' Use their names to help with transcription. Always note stopclock time when taking notes.	10
c	1	Provide some blank cards/post-its and ask students to construct a group-constructed 'diagram' (poster?) of <i>physics subject knowledge required by a physics teacher</i> and to explain their choices.	<b>Make sure the student number the cards/post-its</b> to help with transcription! Take photos of intermediate stages and the final result.	20
D	3	Start with a timeline of the SKE course (co-constructed with them) to remind them what happened and when. Discussion on what they experienced as significant for their SK development.	Be aware of: student responses that focus on <i>teaching</i> approaches at the expense of <i>learning</i> approaches; judgements based on what they <i>liked/disliked</i> compared to found <i>effective</i> and <i>why</i>	35
E		End with opportunity for debriefing. Ask what the process was like.		10
<b>Resources needed:</b> 2 dictaphones; camera to capture statement sort; stopclock; A3 blank paper				



## Participant Information Sheet

**Project title:** The Development of Physics Subject Knowledge by Student Science Teachers

You are being invited to take part in the above Doctorate in Education (EdD) research project with the Open University. Before you decide whether or not you wish to participate, please take time to read this sheet so that you understand what the project is about. Please ask for clarification if necessary and take time to decide whether you are willing to be involved.

### ***What is the purpose of the research?***

This research seeks to develop understanding of how student science teachers think about and develop their physics subject knowledge during an initial teacher education course. The study aims to contribute to knowledge of what physics subject knowledge is needed to become a teacher and what the significant experiences are for student teachers as they embark on their journey as physics teachers.

### ***Do I have to take part?***

No. All participation in this research is voluntary and you may withdraw at any time without giving a reason. If you decide to participate you will be given this information sheet and asked to sign a consent form. If you choose not to participate, or at a later date decide to withdraw, you may do so without prejudice. Your decision about whether or not to participate will not be recorded in any way and will not affect your progress on the course.

### ***What will happen if I agree to take part?***

You will meet with me individually on up to three occasions: soon after the start of your course in September 2012; sometime during January or February 2013; and finally in May 2013. If you agree to participate I will contact you to agree a suitable time and location for the meetings. Each meeting will last a maximum of 90 minutes and you will be asked to talk about your views about physics subject knowledge and your experiences of developing it. These meetings will not form any part of the assessment for your course. These meetings will take the form of semi-structured interviews, focussed on your experience of learning and teaching physics. To enable me to analyse our discussions I would like to audio-record the interviews and I ask you to agree to this.

The audio recordings may be transcribed and you will be offered the opportunity to view a summary of the interview. At the completion of the research the analysis and conclusions drawn will be made available for participants to read. You will also be able to meet with me individually to discuss the research findings.

***Are there any risks/benefits involved?***

There are no significant risks involved in participation, other than the possible inconvenience of the demand on your time.

The benefits include the potential for you to gain deeper insights into your own subject knowledge development. In particular you stand to gain insights into designing and conducting an educational research project from the point of view of a participant, which may be useful when you are required to develop your own research project as part of the PGCE course or during further study.

I anticipate conducting our meetings on days when you would normally be attending the university, to minimise inconvenience to you. If this is not possible then any additional travel expenses incurred as part of your participation in this project will be reimbursed.

***Will my participation be kept confidential?***

Your name and any personal details will be kept confidential, with pseudonyms used for any transcription and the written accounts. Please be assured that your data will be treated with the utmost respect for the contribution to knowledge that you are making.

All data will be stored securely and confidentially. Your name and any personal details will be stored separately from the data and will be password protected. The audio recordings will be stored on a password-protected computer which will only be accessible by me. On completion of the project, personal data, including the audio recordings, will be securely held for six months prior to being destroyed, in accordance with university guidelines.

This project complies with the Freedom of Information Act 2000 and the Data Protection Act 1998. Any data collected will be destroyed upon request.

***Will my decision about participating in this research affect my course or my progress on it?***

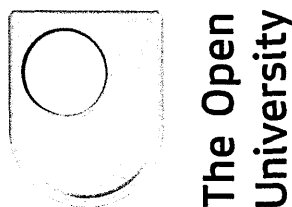
Your decision to participate or not to participate will have no influence on the support you receive from *[location name deleted to protect identity]* tutors as a student and the research will form no part of assessment of your progress and achievement on the course..

**Contact details**

**Researcher:** Michael Inglis  
**Tel:** \*  
**Email:** \*

**Supervisor:** Dr Margaret Smith  
**Tel:** \*  
**Email:** \*

*\*[deleted to protect institution identity]*



## Participant Information Sheet Feb 2013 Update

**Project title:** The Development of Physics Subject Knowledge by Student Science Teachers

In September 2012 you agreed to participate in the above Doctorate in Education (EdD) research project with the Open University. This research seeks to develop understanding of how Physics SKE students think about and develop their physics subject knowledge during an initial teacher education course. The study aims to contribute to knowledge of what physics subject knowledge is needed to become a teacher and what the significant experiences are for student teachers as they embark on their journey as physics teachers.

You agreed to meet with me individually in September 2012; sometime during January or February 2013; and finally in May 2013. The interviews planned for September 2012 were completed and thank you again for taking part: your contributions were much appreciated and valued.

I wish to make a change to the next planned series of interviews. Instead of meeting you individually during February 2013, I would like you to participate in what is called a *focus group* during March 2013, where I would facilitate a discussion of the questions I have been asking you so far during the individual interviews. The focus group will last for a maximum of 90 minutes. As with the individual interviews, the focus group would be audio recorded. Your name and any personal details will be kept confidential, with pseudonyms used for any transcription and the written accounts. Please be assured that your data will be treated with the utmost respect for the contribution to knowledge that you are making. All data will be stored securely and confidentially. Your name and any personal details will be stored separately from the data and will be password protected. The audio recordings will be stored on a password-protected computer which will only be accessible by me. On completion of the project, personal data, including the audio recordings, will be securely held for six months prior to being destroyed, in accordance with university guidelines. This project complies with the Freedom of Information Act 2000 and the Data Protection Act 1998. Any data collected will be destroyed upon request.

Please do not hesitate to ask for clarification if necessary. I wish to remind you that all participation in this research is voluntary and you may withdraw at any time without giving a reason. I will be in touch again soon to confirm arrangements for meeting. I anticipate meeting at *[location name deleted to protect institution identity]* during either w/c 25<sup>th</sup> Feb or w/c 4<sup>th</sup> March. I very much look forward to meeting you again.

**Researcher:** Michael Inglis  
**Tel:** \*  
**Email:** \*

**Supervisor:** Dr Margaret Smith  
**Tel:** \*  
**Email:** \*



**Project title:** The Development of Physics Subject Knowledge by Student Science Teachers

**Agreement to Participate**

I, \_\_\_\_\_ (print name) agree to take part in this research project.

I confirm that I have had the purposes of the research project explained to me. I have read and understood the information sheet provided for the above study. I have had the opportunity to consider the information, ask questions and have them answered.

I understand that my participation is voluntary and that I may refuse to participate at any point by simply informing the researcher.

I have been assured that my confidentiality will be protected as specified in the information sheet.

I agree that the information that I provide can be used for educational or research purposes, including publication.

I understand that interviews will be audio recorded and the recordings treated confidentially. I am happy to proceed.

I understand that parts of our conversation may be used verbatim in future publications or presentations but that such quotes will be anonymised.

I understand that if I have any concerns or difficulties I can contact:

- Michael Inglis (researcher) on \* or \*
- Dr Margaret Smith (supervisor) on \* or \*

I assign the copyright for my contribution to the OU for use in education, research and publication.

Signed: \_\_\_\_\_ (participant)

Date: \_\_\_\_\_

Signed: \_\_\_\_\_ (researcher)

Date: \_\_\_\_\_

*\*[deleted to protect institution identity]*



From Chair, The Open University Human Research Ethics Committee  
Email  
Extension  
To Michael Inglis, CREET  
Subject *"The Development of Physics Subject Knowledge by Student Science Teachers."*  
Ref HREC/2012/#1262/Inglis/1  
Red form  
Submitted 3 September 2012  
Date 10 September 2012

## Memorandum

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, has been given a favourable opinion by the chair and deputy chair of the Open University Human Research Ethics Committee. The application complies with the Open University's code of practice for those conducting research on human participants. You are to be congratulated on the thoroughness and high quality of the application.

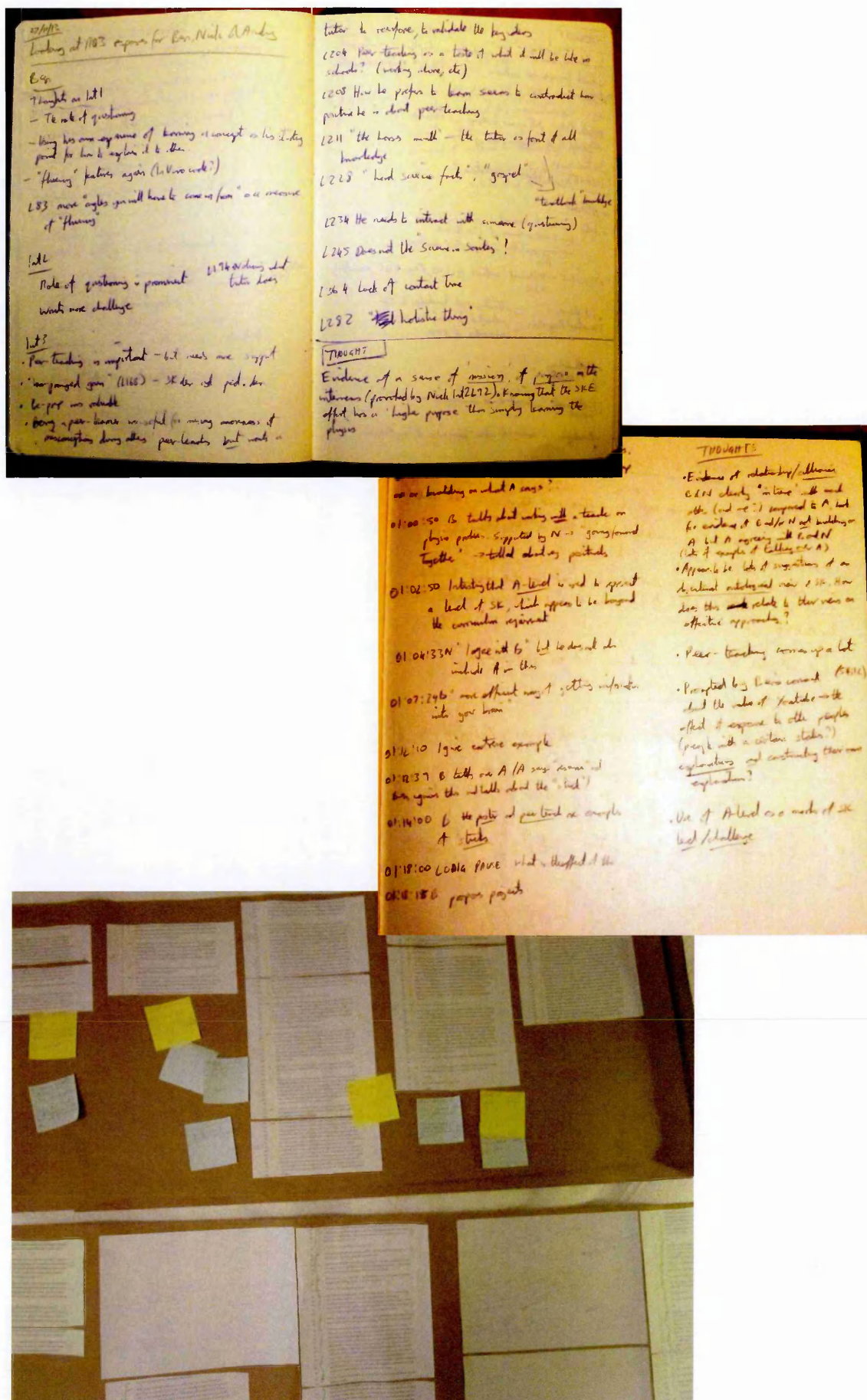
Please make sure that any question(s) relating to your application and approval are sent to [Research-REC-Review@open.ac.uk](mailto:Research-REC-Review@open.ac.uk) quoting the HREC reference number. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Regards,

Chair OU HREC

#### D. Examples of memos and prepared transcripts for analysis



E. Example coding extract for Ben interview 3

Transcript	Content Category	Open coding	Themes
<p>Int Ben</p> <p><i>Asks about significant learning experiences on the SKE course</i></p> <p>It's hard to single out any one thing. I found this hard when we were asked to write about a critical incident. I think it was all really valuable. I think coming into education the second time round I lap it all up and I really appreciate having someone there whose job it is to just teach us stuff. Like it seems amazing to me now whereas when you're a kid it's like you just have to be here and you don't think of it like that. But any one particular thing...I think it was good, well something that I really enjoyed and I think I got a lot from was the peer-teaching sessions where I had to independently learn something and then teach it back to everybody. I think that as well as the subject knowledge aspect which I think was good I think it would have been better if we had also had more sessions led by you guys afterwards to consolidate it. As well as the subject knowledge section of it I think it was really a good confidence booster for coming into teaching this year so I think I gained a lot from that. That was a two-pronged gain.</p> <p>Int</p> <p>So what was the value of that for you? Was it preparing to do it or doing it or being on the receiving end of somebody else doing it?</p> <p>Ben</p> <p>All three had varying values. Doing it, or like researching it or sort of preparing to do it, were good for subject knowledge stuff because you really root around trying to find different stuff out from various sources and you get it explained in different ways and sometimes slightly conflicting ideas so you would have to sieve it all out and figure out what's the right explanation of it and make a little mini lesson out of it, so that was good for subject knowledge specifically, that was very good. The actual delivery of it was good as confidence booster for teaching, that yeah I can do this, I will be alright, and listening to other people's was quite interesting to see. Again I think you have more of a chance to pick up on misconceptions about ideas. You might have read about some stuff and thought 'I'm not sure if that is quite right' while they're sort of telling us now. So that was good for flagging up some areas for the future where people can get that wrong easily, it's easy to trip up over that. So watching other people was good for that and again to think, to try and take, you know, reflectively 'I will try that for myself later on, that was good' or 'I won't try that, that wasn't so good'. I think it was really quite wide ranging set of advantages to doing that kind of work, but I would have liked as well a bit more, sort of, hard core theory after it as well so when you're getting slightly different ideas from different people, like who's right and who's wrong, what is the right answer.</p>	C	<p>Liking the SKE course</p> <p>Changing attitude to learning</p> <p>Learning via peer-teaching</p> <p>Criticising the way peer-teaching was led</p> <p>Feeling confident as a sign of success</p> <p>Learning SK and pedagogy</p> <p>Learning actively (root around)</p> <p>Assessing different explanations</p> <p>Feeling confident is important</p> <p>Reflecting on own understanding when exposed to somebody else's</p> <p>Gaining ideas for teaching</p> <p>Learning about pedagogy</p> <p>Wanting more from a tutor</p>	<p>Having enough SK – affective criterion (confidence)</p> <p>Peer-teaching develops SK and subject-specific pedagogy</p> <p>Peer-teaching encourages/supports deep learning</p> <p>Having enough SK – affective criterion (confidence)</p> <p>Peer-teaching encourages/supports deep learning</p> <p>Interacting during peer-teaching more important than presenting?</p>

## F. Example memo about the effect of mistranscription

### As originally transcribed

Sally It's just new, isn't it, there's no arguments or whatever going on with people, so everybody's like, "Hi, how are you?" really happy. And often as well, when you're first in a group, I find quite a lot of people, probably just intimidated by it all, but quiet or they're shy, and often the ones who are shy end up quite loud by the end of it, when you get to know them anyway. But I keep finding, it's the way I am anyway, when you go to sit down at your table, I'll be the first one to introduce myself and ask who everybody is, start a conversation going, because they'll all be really quiet. People just sit down and not even give you eye contact, and I'll go, "Hello," or make a joke or something, and then they all start laughing, and it eases everybody. And I'm really good at doing that, which is really strange, because there are people who don't know that. I like to invade people.

Int 67:33 Why is that strange? You say it's strange.

### After repeated re-listening and amending ('...' indicates a significant pause)

Sally It's just new, isn't it, there's no arguments or whatever going on with people, so everybody's like, "Hi, how are you?" really happy. And often as well, when you're first in a group, I find quite a lot of people, probably just intimidated by it all, but quiet or they're shy, and often the ones who are shy end up quite loud by the end of it, when you get to know them anyway. But I keep finding, it's the way I am anyway, when you go to sit down at your table, I'll be the first one to introduce myself and ask who everybody is, start a conversation going, because they'll all be really quiet. People just sit down and not even give you eye contact, and I'll go, "Hello," or make a joke or something, and then they all start laughing, and it eases everybody and I'm really good at doing that. Which is really strange...because there are people who don't know that...I like to evade people, on a...

Int 67:33 Why is that strange? You say it's strange.

My question ("why is that strange?") has cut across something that Sally was starting to say faintly, in a quiet and apparently self-conscious way, to expand on her self-description as liking to "evade people". In the context of the effect of group work this might have been a revealing moment if I had noticed what she had said and its significance. Instead, I was not paying close attention. The audio recording reveals (to me) that I am not really focussed on what Sally is saying at this point and my follow-up question has been triggered by her use of the word "strange". I have missed entirely the apparent contradiction in herself she was starting to describe (wanting to evade people while also being the person who will speak in a group with the aim of getting people to interact). In the original transcription the punctuation has changed the meaning of the previous sentence (as well as the mistranscription of "evade" as "invade").

## G. Participants' pre-SKE course histories

### *Nick*

Nick is 28 years old<sup>1</sup> and is from England. He attended a state Grammar School until Year 11 when his family moved to Wales. After completing his GCSE studies he went on to gain four A-levels, in biology, chemistry, physics and maths. He then studied for a BSc in an earth sciences subject at a university in England, graduating with a 2:2 class degree. He worked temporarily on construction sites until he joined the Royal Air Force. After four years in the RAF he was made redundant as a result of government defence spending cuts.

Science subjects appealed to Nick at school due to his enjoyment of their practical aspects and apparent usefulness, with some influence from his step father's background in engineering and his father's background in the car manufacturing industry. Nick studied four subjects at A-level (rather than the more common number of three) due to an expectation from the school that he, as school Head Boy, should aim to get into an Oxbridge university (which would have been an unusual achievement for a pupil from that school). However, he found some of the A-level concepts more challenging than he expected and chose not to revise for some of the Maths exams. He was not particularly interested in going to Oxbridge, but he was encouraged to attend an interview for natural sciences at Cambridge, in which he was unsuccessful. Nick identifies one school teacher who had a particular impact on him and who he refers to several times in interviews when discussing his own teaching and learning preferences:

there was quite an eccentric character, [...] and he always used to wear a cravat, drive steam trains, worked at a nuclear power station. He was always you know, really bringing home real life examples to us of the physics we studied in school so he was inspirational in my enjoyment in physics and life sciences throughout the school. (Nick, interview 4)

Looking back at his prior experiences as a learner, Nick is quite critical of the teaching and learning environment when he was a university student...

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<sup>1</sup> The age of each participant is at the time of interview 1

I found the lectures very disjointed...I was 18, I was a bit immature and I didn't really fully realise what was expected of us in terms of non-contact hours, self education and there were so many more distractions and temptations at that age, moving away from home for the first time. [...] I remember being in a lecture learning something about how cobalt moves through the sea floor and I was thinking, why, I don't care, I really, really don't care. And they didn't provide us with any real life world examples or any reasons why this might be important (Nick, interview 3)

...but, he recounts positive memories of learning physics in the RAF where the abstract concepts he was expected to learn were related to him so that they provided a "direct connection" (Nick, interview 1) to his day to day experiences around aircraft.

When he was made redundant from the RAF he explored teaching, part of the appeal being that it involved working with people and would lead to a career and not a nine-to-five 'job'. Nick was not familiar with the SKE course concept when he came for interview for the physics PGCE course at Albion University, but he recognised that the SKE course would develop his confidence in the subject and would enable him to achieve his aim of becoming a physics teacher. During my early work with Nick as a course tutor he struck me as practical, pragmatic, goal orientated and inter-personally skilled, with a focus on quick decision-making, high standards and attention to detail.

## **Ben**

Ben is 28 years old and is from England. He attended a state comprehensive school until the age of 16, where he gained eight GCSE qualifications, and then went to a Sixth form college, where he gained A-levels in biology, physics and computing. Despite being interested in physics, Ben's superior biology GCSE grade led him to study biology at a university in England. Ben thinks now that he chose his sixth form subjects based on his enjoyment of them or what he did well at, rather than a result of a vision of what he wanted to go on and do when he left school, or as a result of careers advice. When Ben started his BSc, he was initially on a biology course, which he studied for two years, and then chose to specialise in ecology because he wanted to "be outside"

and did not enjoy laboratory-based work. He graduated with a 2:1 class BSc and sees this as a fair result for the effort he put in.

Ben then worked in ski resorts in Europe, running a small business with a friend creating holiday videos for skiers. They had some success and he now has some regrets that they did not try and make more of it. On returning to the UK he worked in a medical environment in a personnel management role. Ben applied to become a teacher during his two years of office work, partly because he realised he did not want to do an office-based job, involving lots of computer work, in the longer-term. He applied for the biology PGCE course at Albion University and was introduced to the SKE course idea during the interview day. Ben was happy with joining the physics SKE, based on having always enjoyed physics and maths at school. Despite gaining a B grade for GCSE maths he did not choose to study maths at A-level, which he attributes to low expectations in his school for pupils to go onto further study. The Sixth Form College had higher expectations although Ben does not describe himself as a good student at that time due to his many interests outside of college. Ben had always had some interest in teaching from when he was at school. His father was a teacher and now teaches in an international school abroad and his mother is a physiotherapist. Ben is not aware of any obvious physics influences in his family background, other than his grandfather is “quite smart”, into “engineering things” and had his own business renovating and selling old machinery.

On gaining QTS Ben anticipates selling himself as a teacher of physics and biology, and KS3 science. Ben is clear throughout all of the interviews that his primary motivation for becoming a teacher is to do something of social value and to work with children:

I wouldn't have thought that I was eligible, to start with, to be a physics teacher, not having a physics degree, until the sort of SKE course idea was floated, and I wouldn't really have gone that way anyway because I would've rather... at the time I would rather have just got it done in a year and cracked on with it, and so that would've meant Biology. But [...] I wanted to teach, I'm not that fussed about my subject. I think Science is a great subject and it's important but so are most of the other ones as well, and it's more the teaching and the interaction with kids and the doing something of some sort of



perceived social benefit that attracts it to me rather than Science per se. So physics or not physics, it's sort of a bit of a moot issue for me in choosing a career. (Ben, interview 4)

For Ben the physics SKE course provides a vehicle through which he can become a teacher and work with children. It is the working-with-children aspect that is most important to him, with the subject through which he does this forming a secondary priority.

### **Andy**

Andy is 23 years old and is from England. He attended a state non-selective secondary school where he gained eleven GCSEs (including separate sciences), before going on to study six subjects at AS-level, including 3D product design & technology to pursue an early interest in becoming an electrical engineer. He achieved A-levels in biology and chemistry during the following year, but had to re-take AS-Level physics. After an additional year at school Andy gained a full A-level in physics, achieving an E grade. He went to an English university to study forensic chemistry, graduating with a 2:2 class BSc degree.

Towards the end of his BSc it became clear to Andy that there would be few jobs in forensic science

the country was just starting the recession and you know the government announced that they were closing down the FSS [*Forensic Science Service*] which was my forensic science provider because it was making an exceptionally big loss and they were going to privatise it [...] I really thought about it and my mum, you know, it was my mum who made the suggestion, she said, "Well, what do you want to do?" I was like, "Well, I really want, I really like helping people," which was my initial motivation for being a teacher (Andy, interview 4)

He then applied for the chemistry PGCE course at Albion University. During the course selection day he learned about the SKE course and received an offer of physics PGCE conditional on completing the physics SKE course, instead of a place on the chemistry PGCE course.

There is no family history or connection with physics that Andy is aware of. His father recently achieved his English GCSE and a Bachelor degree in cultural studies. He has a sister and brother in secondary school and a sister who is studying zoology at Albion University. Andy describes his mother as his “main influence” by helping him to explore subject choices at school and university.

### **David**

David is 23 years old and is from England. He attended a private boys-only school for all of his primary and secondary education. This school shared a site with a girls-only school, although pupils were only allowed to mix at certain times and locations in the school grounds. David gained ten GCSEs, including biology, chemistry and physics taken as separate sciences. He then studied five subjects at AS-level and went on to achieve full A-levels in biology, chemistry and physics. David worked in a cafe for a year in order to save some money and then went to a University in England to study biological sciences. During his course, David specialised in neuroscience and graduated with a 2:2 class BSc.

He attributes his wide-ranging subject interests, including humanities and all three sciences, to his parents’ professional interests in science and humanities, but does not regard his father’s professional role as a doctor as playing a significant role in his interest in neuroscience (although he is aware that there may have been some expectation amongst other family members that he might study medicine). David attributes his choice of neuroscience to his interest in the “mystery” of the brain as something we “do not know all the answers about”. He was successful in lab-based activities and essay-based assessments, but did less well in exams which require “regurgitation of knowledge”. David had a grandfather who was an engineer, although he is not aware of his grandfather’s professional background playing an obvious role in stimulating his interest in physics.

David decided he wanted to be a teacher before he completed his GCSEs. What he calls his “plan A” was stimulated by people (such as classmates in a Biology class) telling him he was good at

explaining things. He felt passionate about education and enjoyed his schooling. During his BSc he enjoyed working in a laboratory and becoming a teacher became “plan B” compared to the new “plan A” of doing lab-based research. However, towards the end of his BSc, as he became aware that he was not going “to do very well” and end up with a 2:2 class degree, he realised he was not likely to get a job, especially with the number of graduates from his cohort chasing a limited number of jobs in the field of neuroscience. Becoming a biology teacher reverted to being “plan A”. David became aware of the SKE course during interviews for biology PGCE courses at Albion University and one other university. When offered the choice of the physics or chemistry SKE courses, David chose physics as he had always been more interested in it compared to chemistry.

### **Charlie**

Charlie is from England and is 27 years old. He attended a mixed-sex comprehensive school which catered for pupils in Years 7 to 13, but the Sixth form closed while he was in Year 10 so that he had to attend a local Sixth form college to study A-levels. After gaining ten GCSE qualifications he went on to gain A-levels in chemistry, physics, biology and maths. On leaving school Charlie worked in a café for several months before deciding to go to university to study for a BSc in chemistry with a view to becoming a teacher. Although he passed his early modules he felt torn about continuing with his studies:

I was too young. That was one of the reasons I dropped out; I just felt kind of futile. I was 19 and going “I want to go into teaching”, I thought “What do I know about anything at this point?” So I just kind of did what I wanted to do. I thought “You can’t really teach kids to pursue their dreams and their passions if you don’t do it yourself”. (Charlie, interview 1)

His strong interest in music led to him dropping out of the course after a year to join a band as a guitarist and spend the next four years touring, and then running his own music production and promotions business. Charlie describes his decision to pursue teaching seriously in terms of a particular moment:

I was actually watching *The Ascent of Man* one night, and just I really got into it and then it kind of became really apparent to me that education was the cornerstone of society, that was the keystone; the ability to pass on information was what keeps us going, that kind of defines us really. And I think they call it extra-somatic information where you can record things externally and that was Sagan, and I just thought "Wow, that is the point isn't it?" That's the bit that clicked. (Charlie, interview 1)

Charlie returned to university and achieved a 2:1 BSc in chemistry. When he applied to the Albion University PGCE course he was interested in following the physics SKE route, rather than joining directly the chemistry PGCE course, because it would make him "more employable" and he could make use of his strong interests in electronics and the role of computer technology in science education:

I was in with a bunch of guys at Uni who were computer science students and they were talking all about the Raspberry Pi...and kind of where education's going...So during that year I was learning to program as well and electronics and just trying to make myself as good as possible I guess, ready for when I went into it kind of prepared for the future of teaching, because it's really heading towards computer science and programming. Everyone thought I was mad but then in February Michael Gove made computer science compulsory so this is kind of like "Well, you know..." (Charlie, interview 1)

During the interviews Charlie is initially not aware of any strong influence from his parents on his interests in science and computing (his mother worked in a telephone call centre and his father works in a factory). In the second interview (several months into the SKE course) he recalls the significance of the influence of his grandfather (who was an engineer) in stimulating an early interest in science and nature.

## **Jen**

Jen is 25 years old and is from the Republic of Ireland. She attended a mixed-sex multi-denominational secondary school where she achieved Irish Leaving Certificate qualifications (taken at age 18 in Ireland) in eight subjects, including maths, chemistry, biology, agricultural s and physics. When she left school Jen was clear that she wanted to use sciences in a role that

involved helping people. She initially wanted to study medicine but did not have sufficient Leaving Certificate grade points. She was offered a place at a university in Ireland to study for a BSc in radiation therapy. Jen was unsure about starting this course straight after leaving school, so she took a year out to earn some money and try to improve her Leaving Cert grade points, before starting the course and eventually graduating with a 2:2 class BSc.

After graduating, Jen spent a summer teaching English at her old secondary school to students from Europe. She then worked as a radiation therapist in England and Ireland, where she also gained some experience with training of university students on hospital-based placements. Her teaching experiences, combined with some dissatisfaction with her working conditions, led her to pursue a long-standing interest in a career in teaching. When she was at school she tutored neighbours' children in maths, but she did not have confidence that she could work with teenagers as a teacher. In recent years she has gained experience of working with children while playing football:

I get on really well with them, and I find myself helping them with their homework as well. So I really enjoyed it and I just thought maybe teenagers aren't that scary. I think I can handle them at this stage now that I'm older. (Jen, interview 1)

It was only once she felt she had sufficient self-belief that she applied for a physics PGCE place at Albion University. She was assessed as requiring successful completion of the physics SKE before she could join the PGCE course, a decision she was not initially happy about:

I wasn't very positive at all because it was based on the fact that they didn't think there was enough physics in my degree. And I suppose if you analyse my degree and look at the credits and everything there might not have been enough, but I didn't feel like I didn't know it. Like even now I feel if I was given a couple of weeks to revise I'd know the whole course. And up until a couple of months ago my brother was doing his Leaving Cert and I was tutoring him with his physics and I didn't have any trouble with it, so I didn't really think I needed it. I mean if anything maybe I needed to brush up on chemistry and biology. And then the idea of doing physics with maths came along, rather than just straightforward physics [...] So if it means that I can get better at the maths end of things and do physics with maths next year then it'll be worth it. (Jen, interview 1)

Some universities are offering a PGCE physics with maths course, which is of interest to Jen. She describes herself as wanting to “have a good grasp of maths” so she can teach it alongside all three sciences at secondary school level. Jen is not aware of any family members, or other people close to her, that influenced her interest in sciences and mathematics. Throughout school she had an interest in sciences, which she pursued despite often being the only girl in the class:

I was a bit of a tomboy and I hated business and I hated the idea of sitting in front of a computer or anything, I always just wanted to know how things worked. And then anyway I struggle on and I was probably one of the better in the class, but my teacher was actually quite poor. She’s lovely woman but she wasn’t a great teacher. So I went and did grinds on Saturdays in Dublin in a grind school. (Jen, interview 1)

The “grind school” is a series of Saturday seminars that revised the school science syllabus, attended by a hundred or more school students. Jen describes the grind school as a positive experience as the teacher was

very engaging. Everybody listened to him. He was very, very good at simplifying things and building them on so you got the whole complex model (Jen, interview 1)

It appears that the clarity of the explanations was only one of the attractions, the other one being the notes which were produced and circulated

Those notes actually are like gold dust; you nearly pay for the notes themselves because they take maybe five chapters of a book, realise that only certain parts are relevant for the exam, and they’re the parts that you got in the notes. So you only ever had to study what was relevant and coming up in the exam, which basically put your workload right down (Jen, interview 1)

## ***Daniel***

Daniel is 24 years old and is from Northern Ireland. He attended a high-performing secondary school, where he passed nine and a half GCSEs including Triple Award Sciences and an RE ‘short course’ worth half a GCSE. He went on to gain A-levels in physics, biology and media studies, and

twice failed to achieve an AS-level in chemistry. Daniel enjoyed sciences (physics was one of his favourite subjects) and he initially cannot explain why he struggled so much with AS chemistry:

It obviously just didn't work for me. I don't really know. I mean I, as I said, re-sat the exam and I revised and revised and revised, but it obviously just wasn't going in and it wasn't clicking and I just was completely getting the wrong end of the stick. (Daniel, interview 1)

He is quite critical now of how his secondary school supported him with re-taking AS chemistry and thinks that the school "looks after it's A star pupils and [if] you're not getting the A's you sort of fall by the wayside a wee bit". After leaving school, Daniel went to university in Northern Ireland and graduated with a 2:2 class BSc in biology. After graduating Daniel spent the following year employed by his parents' small business. He is disappointed by his degree classification and thought he might have been able to get a 2:1 if he had also not been working for his parents during his final year. During the year following his graduation, Daniel also studied a part-time post-graduate course in biology and gained qualifications in instructing archery and canoeing.

During his BSc Daniel considered science career options and decided that a biology-related career would involve being "stuck in a research lab", which did not appeal to him. Daniel describes his interest in becoming a teacher as developing over a period of time and influenced by his experiences as a scout leader and perhaps influenced by his parents, who both trained to become teachers before starting a small business. He applied for a PGCE teaching course in Northern Ireland, but did not gain a place immediately due to the course there being very oversubscribed. Daniel then applied to Albion University for PGCE biology and found out about the physics SKE course during the interview day. He decided to accept the physics SKE offer as an appropriate route to being able to do what he wants to do, which is teach science. When he achieves QTS Daniel sees himself as becoming a science teacher who is able to draw on his grounding in biology and also his preparation to teach physics.

## H. Example transcript (Nick interview 3)

- Nick I'm still going to stick with the structured approach (writing "classical physics" and "modern physics" on diagram). And then I could list a whole lot of things I know, like Newtonian physics, for example.
- Int 24:15 Give us a couple of examples.
- Nick (Writing "gas laws", "light") and then... I think something that I don't think I had on last time was to do with astronomy. Just chatting with a couple of people who weren't on the SKE course but have started a PGCE this year... Astronomy is something that I didn't really think a lot was done about in schools but it turns out that it is. I don't think it really formed much of the... It wasn't taught when I was in any stage of my physics education, I don't think. So I'm going to put astronomy down and I'm going to put it in the middle, (writing "astronomy") because there's a lot of links to classical physics with Newtonian physics and forces, circular motion, that sort of thing, but then with astronomy you've got the... It's always... There's always a new thing that's been discovered and new theories being conceptualised. And I think that links really nicely with... Because it's on such a massive, massive scale, I think it links really nicely with the modern physics, like quantum physics and looking at things smaller than the atom, because then you can ask big questions like what's the start of the universe, what happened, what's the nature of matter and suchlike, and I think... It's probably because I was watching a television programme on it the other day actually, but it really links that to epic scales of physics in terms of dimensions. I'll put that in capitals, linking that. I'll just put a couple of names down here as well (writing "Einstein", "Bohr", "Heisenberg"). I'd also put down, probably in the middle, (writing "history of physics"). I think that's something that can link to classical and modern, because then children in school, from age 11 to 18, could appreciate and link other subjects like... Obviously history's the prime one there. They can link the knowledge about learning history with their physics subject knowledge and see where these things fit in. And I don't think we did too much of that in school but that's something that I'd like to see more of included in physics subject knowledge because you can organise it in your mind then, get a sense of when these things were discovered, who discovered them. You've got that human element and then it would help you remember them a lot more. So...
- Int 27:44 That classical modern split seems to be quite significant for you.
- Nick Yeah.
- Int 27:51 Where does that come from for you? Why that split? Why does that...? Because that's almost like your starting point with how you've divided things up, so why is that?
- Nick I think, myself I've developed a bit of knowledge of the history of physics and science with this year and last year on the SKE as well, and there's very much that paradigm shift [laughter] with...
- Int Well remembered {laughing}
- Nick ...with these concepts, over on the left the classical physics and then the modern physics, and that's one of the biggest shifts in our understanding of physics subject knowledge that's ever happened. And I like structure and I think for me, if I had learnt in a slightly different way last year, I might have structured it a different way, but that's what works for me in terms of recording as easily as possible what physics knowledge is. I'd instantly go for that split and then let the actual topics fall out then.
- Int 28:54 So when you're learning about these things... And pick some of these topics, like the gas laws, for example. What is it you're imagining when you write that? Is it learning all theory? Is it somehow doing or applying the gas laws or...? What are you imagining when you write that?
- Nick When I'm saying gas laws as an example, this is something I think goes back to my time in school, quite a pragmatic approach, I imagine some of the equations that are involved in



that because they're obviously some of the things that rightly or wrongly you're tested on in school. Well, obviously rightly, you need to know the equations, you need to have a lot of good understanding of maths, but I think sometimes the way people are tested in schools, you could just record an equation and not necessarily know what's going on but if you can plug the numbers in and get the right answer out, tick, you've done that. So for me, back from my school days, that pragmatic approach, when I think about something like the gas laws, I think about the equations that are associated with it. But more and more now I'm starting to think about how would I teach it, how can I demonstrate it, different types of learning and teaching strategies and suchlike. So I want to get away from that just sense of, right, this is what you need to do for a test, to pass some questions surrounding something like the gas laws, and really get people to understand what it is.

Int 30:25 Right, okay. And where or how or if... Does maths fit into this, do you think? Just for you, does maths belong...? Is that part physics subject knowledge or is that a different subject knowledge?

Nick I think that as much as possible different subjects in school should blend into each other. I think that would really... It certainly would have helped me in the school. I've spoken to a couple of my colleagues and I think they feel the same, because the more you can see overlaps and links to other subjects then the easier it is to learn. And with maths, I think it's a really, really important tool in physics. I think it's all well and good to learn as much qualitative stuff as you can, but I think that's only useful up until a point. I think to utilise maths in physics content is essential really to understanding and using a lot of the concepts. For example, we did that work on the car engine last year and you could describe and explain how an engine works and so on, but if you don't know how much energy you're getting out of it versus how much energy you're putting in, i.e. how efficient it is, it's not going to be very useful to you in terms of designing something or engineering something. So I think maths and physics... More than a lot of subjects, pairs of subjects, maths and physics really lock together well and blend in together well.

Int 31:53 And are there any of these you think that are going to be particularly important for you this year?

Nick Any of these particular...?

Int 32:03 Any of the things you've got on there.

Nick I think this year, for me it's going to be quite a struggle to... Not a struggle but it's going to be a big challenge to learn the curriculum, exactly what's on it, because it's always changing. Everything's just changed recently. So something like the history of physics will help me to learn what's on the curriculum, what's exactly required for me in terms of my teaching, and then knowing where all these things fit in with respect to that, like the history of physics. And then something like astronomy, just to take an example there, using that as a tool to inspire the kids really and help them understand the scales of different things. Yeah, the timeline (inaudible 32:58) is to do with history, isn't it, yeah.

Int 33:01 Should oceanography be in there? How does that fit, do you think?

Nick Oceanography? Let's have a think... I have to remember what I actually did [laughter]. Yeah, there's a lot in, for example... If I take an example of learning about specific heat capacities or something like that, that's something that you learn the theory about in school and then when I went on to university we learnt about that in terms of how does salinity affect specific heat capacity and suchlike and the different other constituents as well. But I wouldn't put oceanography on there, I don't think, because I like to see more applied stuff, like engineering type stuff. I think that I could relate to that more, thinking back to what I said earlier about my degree and suchlike, and I think more kids could really as well. Because there's only a small number of pupils who are interested in science anyway, who choose to take it, I think as much as possible to engage in something that's more related to their everyday life and everyday experiences, like cars and houses and energy, would be more

useful than including something like oceanography where it's quite abstract and not a lot of children would be able to relate to it.

Int 34:23 Okay. So again, at this point, if, what, when, I suppose, you're asked by pupils in school, what's different about physics compared to chemistry and biology and what do they have in common, what would you say?

Nick Well, I think from my own last couple of weeks' work we've done on what is science, I think that science is a body of knowledge and it's also a way of thinking. So in terms of the difference between physics and chemistry, physics is obviously a body of knowledge that is physics. And I think it's important to categorise different ideas and concepts as either like physics or chemistry. And they'll have overlaps, but I think you just... You need order, you need structure in your thinking and your mindset. So I think that physics is different in that way because it's actually different knowledge about what you know about different things. And the common theme then between the different sciences would be the methodology and the way you go about thinking about doing physics, doing chemistry. There's still a scientific method, which is the old, like you observe phenomena in the natural world. It could be biological, it could be physical, it could be chemical, and then you come up with a hypothesis, test it again, test it again, and then come up with a theory of, this is why what we've observed is happening. So that's common to all three sciences.

Int 35:53 Right, okay. So let's say a physicist and a biologist, if I understand that correctly, what you've said is what they have in common is scientific method and those kinds of intellectual tools at their disposal and procedures that they might follow, and what they've got different is a different body of knowledge.

Nick Yeah.

Int 36:18 So is the difference in the body of knowledge, is it just... How can I put this? What's the difference between these two bodies of knowledge, or is there a difference? Is it simply the topics that they happen to cover or is there something more different than that, do you think?

Nick I just think it's what you know. If you know that DNA is a double helix spiral and you can draw a chromosome, that's something you know, that's categorised as biology. And if you know that  $F = ma$ , that's physics and that's categorised as physics and that's something that you know. And sometimes you could have a scientific problem where you need to know different facts and understand different processes from the three different sciences, but I think that should still be compartmentalised into... Sorry, categorised into one of the three sciences.

Int 37:22 Do you think, do physics... Think of like an average or a typical, let's say, physicist instead of a biologist or a chemist for that matter. Do they in any way think differently?

Nick I think I'd need to know a specific problem that they were thinking about. I think when you automatically... You start thinking about atoms and stuff if you're a physicist, but I don't think... If they're doing some research or something like that on a particular issue they'd have to draw on pieces of their own knowledge and research pieces of knowledge that they didn't already know, but I don't think the way they think is different, no. No, I don't.

Int 38:09 Okay. So if we think about your experience last year on the SKE course, and maybe the week or so you've had on the PGCE so far, what experiences have you had during that course that have been significant for you in terms of developing your physics, understanding your physics subject knowledge? Is there anything that you look back at and think, that was significant for me in some way? It could be a one off or it could be something that happened a lot that you now look back and think, yeah, that was important.

Nick I think... I just enjoyed the slow steady accumulation of knowledge that you get from lectures, where you are expected to pay attention, someone's talking to you and you're actively engaging with them, asking questions and then you go away and do your own

learning. So I really enjoyed that aspect of it and that was really very significant for me because it's a slow steady process and it's hard work. And I like some of the things that were required of us, like the microteaching, where I think to learn about something and to teach it to someone else is the best way of learning about it yourself. So I think that was really useful and I had quite a few light bulb moments, as it were, last year.

Int 39:31 So what you said there about the lecture and that slow accumulation of knowledge, how does that fit with what you said earlier on about your experience on your degree, where one of the things that put you off or demotivated you was you felt you were being lectured to a lot. So how do those two things match?

Nick I'd say that they're different because they... Last year on the scheme it was very much a sort of informal style learning, asking questions as and when required. On my degree course it was a room with a very much larger amount of people and I didn't feel that same steady accumulation of knowledge because I found the lectures very disjointed. As I said, I think I was just... I was 18, I was a bit immature and I didn't really fully realise what was expected of us in terms of non-contact hours, self education and there were so many more distractions and temptations at that age, moving away from home for the first time.

Int 40:35 Surfing no doubt being one of them {laughing}

Nick Yeah [laughter]. Yeah, so I didn't take that on board really. And I remember being in a lecture learning something about how cobalt moves through the sea floor and I was thinking, why, I don't care, I really, really don't care. And they didn't provide us with any real life world examples or any reasons why this might be important, so it was just like learn about this process for its own sake. I remember thinking,, why, I don't care about cobalt, why. It was so boring. But then obviously last year that was contrasted by the fact that the emphasis was very much on, right, you need this body of work, you need to learn this body of knowledge, because you're going to be a teacher, you're going to be teaching other people about it. And there were plenty of examples about why it's useful, where it can be thought about in everyday situations and where it affects our lives. So it was much more motivating last year and so far this year, this last couple of weeks.

Int 41:42 You said there about micro teaching, that that seems to have been significant for you.

Nick Yeah.

Int 41:47 And you mentioned about light bulb moments and so on. So what is it about that for you that was significant?

Nick Just in terms of physics subject knowledge?

Int 42:00 Yeah, in terms of developing your physics subject knowledge.

Nick As I said really, I just think that when you know you're going to get in front of a group of people who are as intelligent as you are, if not similar knowledge, you're going to have to perform really, you're going to have to obviously demonstrate that you know what you're talking about. And it's the best way of learning yourself then because it's like, right, I've got to know exactly what I'm talking about (inaudible 42:28) as we know in science, sometimes they're key. You've got to be very descriptive, very accurate with the language that you're using, so it forces you really to understand an issue and make it interesting and make it easier for people to understand.

Int 42:46 So was it the preparing to do it? How did that rate compared to actually doing it?

Nick Both really because preparation... As I say, you have to get it all squared away and know what you're going to say, know what questions you're going to ask, what teaching strategies you're going to use to introduce to develop a person's understanding and improve their knowledge. Then when you're actually doing it... Because of the nature of what we were doing then it was a peer team, a microteaching session, somebody might ask a question and then while you're actually teaching it you think, oh yeah, I didn't think about it that way. And

you might not be able to answer the question but somebody else within the peer learning group might be able to answer the question. So you're still learning about the dynamics of the classroom and how your knowledge could be increased in that situation while actually, well, you're meant to be teaching.

Int 43:48 Are there any examples spring to mind?

Nick I think when we did the gas laws actually, funnily enough, going back to them. Yeah, the different equations and the different... Like the kinetic model theory, just having to learn about all that and then having to teach it. And... I can't remember a specific question I was asked but I can just remember the amount of work and effort that I think myself and a couple of others, like in a little team, put in to learn about it. And then we were actually teaching it you could see people understanding it then and how it links the different laws. So that was very useful.

Int 44:37 So the act of doing it is at least as important for you as the preparing to do it.

Nick If I put some numbers on it I'd probably say about 60/40 in favour of preparing it yourself in your own time, helps build your own physics subject knowledge.

Int 44:53 So if you were told, prepare to do a microlesson or prepare to explain something, and you did all of that and on the day it was like, actually no, we're not going to do that... So apart from the fact that you'd probably feel a bit frustrated about that, would you still have got any benefit from that?

Nick Oh yeah, massively, yeah. As I say, you do most of your learning in preparation. But then, as I say, if I had to put numbers on it, it would be about 60/40, 70/30, something like that, in terms of how it helps you develop your subject knowledge, so obviously in favour of the preparation. But then on the day you still learn stuff.

Int 45:34 And what's the importance for you of doing it as part of a group as opposed to doing it on your own, so just being you to your whole group, on your own up there, preparing that thing... Because you were in little groups last year doing that.

Nick Yeah, yeah.

Int 45:47 How significant was that for you?

Nick In terms of developing my subject knowledge still?

Int 45:50 Yeah.

Nick You obviously don't want to miss out on any knowledge that someone else has researched, and similarly you don't want someone else to miss out on knowledge that you've researched for your bit. So you've just got to work with them really. And that's something that comes naturally to me, working as part of a team, from my time at the RAF. So you've just got to liaise and delegate, and they're all skills that we're going to be teaching. But in terms of developing subject knowledge, I suppose effectively when you're microteaching, even though, say, there's three of us stood here and there's the group of 12 that we're teaching, they're still listening to you as you're describing something so they're still learning from you and vice versa when they're speaking.

Int 46:33 Did it work for you as a learner? So when you were one of the peers being taught, what was that like for you? Did that do anything in terms of developing your physics understanding?

Nick Obviously it was... For us it was that sort of first time of standing up in front of people, teaching something that we'd had to learn perhaps only a few days or a couple of weeks before. So some of the physics that was being explained and discussed was a bit woolly sometimes and I would have liked a bit more. I felt like sometimes I did have to supplement it with my own learning in the background. But it was interesting to see how people went

about doing it themselves and how they explained it and stuff. Because there were like two or three people in a group or four, they sometimes overlapped on what they were saying, so just literally different sentences and different ways of saying things, how they explained it differently, helps develop my subject knowledge.

Int 47:40 When you mentioned about being asked questions by some of the peers that you're trying to teach and you might think, oh, I hadn't thought about it that way, when you were asked that question, what difference does it make to you if that question's come from one of your peers compared to, let's say, one of your tutors?

Nick Well, I guess they genuinely don't know the answer, whereas you'd hope your tutor knows the answer but they're trying to assess your knowledge and your thought process. So when you answer you've got to... I suppose if you know it, you know it, you're going to give the same answer to both, aren't you?

Int 48:21 Or will you? I mean, you asked that as a question. I mean, would you do...?

Nick Yeah, yeah. But then, I mean, probably you give them the answer to the question they were asking and then you may say like a supportive statement, like do you understand where that fits in with what we were learning just now, whereas you wouldn't obviously say that to your tutor because they're just trying to assess what you know

Int 48:43 Right. So is the purpose of the question important? So if it's a tutor asking the question, because you're assuming, well, the tutor obviously knows so they're asking the question for some sort of assessment purpose or to further your learning, is that different then, the fact that if your peer's asking a question it's probably because they don't know?

Nick That's right, yeah.

Int 49:05 So is that the difference, do you think?

Nick I think so, yeah. So you've got to... Because you probably know because you've done the research for that particular session of microteaching, you need to then check your understanding and maybe try about two or three or four different ways of saying it. So then a different way of saying something can often... They can actually grasp it then. Sometimes they don't on the first couple of goes.

Int 49:33 What's it like if one of your peers asks you a question about physics and you don't know?

Nick In a microteaching session or...?

Int 49:42 It can be a formal or just any setting. What's that like?

Nick You just say you don't know and then... You work on it together. "I don't know actually, where could we go and find out?" We've got textbooks or go and ask yourself another tutor.

Int 49:59 That's what you would do but what does it feel like?

Nick I suppose at this stage, two weeks into the PGCE, you think... I have thought to myself, oh, hang on a sec, if that was a kid you can't just go, "I don't know, what are we going to do about it?" You can't just... You obviously don't lie to them so you've just got to be honest, haven't you, and just say I don't know? So the feeling is of trepidation really, I suppose, thinking in a few days or weeks time we're going to be in a classroom environment so it's going to be different then. And you're thinking perhaps I should know this by now, but I think you can't always know everything, so...

Int 50:37 Well indeed, absolutely. I would love to know everything. But when you think of what's going to come up in the next few weeks, starting your placements, etc, who knows. I mean, it's possible, for example, that you may get some experience of teaching a physics GCSE class even a couple of weeks before Christmas. It's probably more likely that you'll be doing Key Stage 3 but not necessarily. So if you'd been told, I want you to have a crack at

teaching that lesson in a few days time, and it's some Year 11 high set physics class, as unlikely as it might be but it might happen, how would you go about making sure that you know your physics, you understand the physics well enough in order to teach it? What would you do?

Nick I'd probably look at, in the first instance, what's being required of them. So at home I've got a GCSE physics revision guide, so I'd probably look at what they need to know and then I'd look for a bit more information about it so I can introduce like a couple of harder... A bit of a harder concept for people who are asking harder questions. And then you'd say to them, "Oh, I'm really glad you've asked that. It's not actually on the syllabus but this is the answer." And you look good as a teacher and that gives you confidence. And then I'd probably look at some sort of supportive stuff, like what's the history of that particular discovery or that particular concept in physics, so they can link it to somewhere else then. So I'd probably look at it threefold.

Int 52:13 So would this be your own, like solo homework you'd be doing?

Nick Yeah, yeah. And there's online resources, looking at how to teach that, and then I'd be looking at, could I use practical elements or what teaching strategies could I bring into that. And then just get on Facebook to the forum that we've got, the PGCE science, or just go directly to a couple of the guys or girls that I'm friends with on the on the course.

Int 52:42 And what would you do, would you ask them questions about the physics?

Nick Yeah, just message them, just say, have you done anything relating to this topic, to such and such a year group. And they might say yes or no or what worked, what didn't, that sort of thing.

Int 52:57 So would that come after, do you think, you've had an initial look at the books or websites? Is there a sequence of events in your mind, you'd hit books first and then ask people or the other way around?

Nick Yeah, I think... From a textbook, say you've got an A3 spread like that and it's on electromagnetism, you can get a lot of information. Even for like half an hour, if you sit down and you think, right, well, if I teach a lesson and I get through all of that, I'll be doing really well. And have that open on the desk in front of me when it's going just as a little bit of a comfort blanket, I suppose. But then in your own mind you'd know most of it then. But then if there's anything that you can't grasp or if you're looking for a particular way of saying something, if you don't think the results that you've got explain it well enough then contact colleagues or tutors or whatever.

Int 53:53 So when you say colleagues do you mean like your peers on the course or do you mean colleagues in the school department?

Nick I'd probably do colleagues... No, I'd probably do people in the school first actually, yeah, when it comes to mention it, because they're going to be readily on hand, aren't they, like face to face, which I find much better than contacting people by phone or email and stuff because they can't get away then, can they? [Laughter]

Int 54:18 But how do you think you'll feel asking a colleague in the school about the physics that you're going to be teaching? Because would you be feeling, well, I'm supposed to know that, so would that get in the way?

Nick Not for me, no, because you've got to... At the end of the day, what's most important is the learning of the pupils, isn't it, so if you don't know and you keep quiet then they're not going to learn as effectively as they could have done. So if you just say to someone, "Oh Dave, what's the formula for this?" Or "How do you explain blah blah blah?" Then they might look at you and think... They probably won't because... I think when I was in the school last year, someone came in and they said something and I was thinking, and you're a chemistry teacher and you don't know that, I'm not even a chemist and I know that [laughter]. I can't remember what it was but they said something and I was like... And loads of the science

teachers were there going, "I don't know either." I was like, well, if they don't know then that gives me a little bit of a light at the end of the tunnel.

Int 55:27 Feel a bit better about that, yes [laughter].

Nick But I wouldn't have any anxiety about asking.

Int 55:32 Would it be different if you were asking... Because in the example you gave there about the formula, you're asking, what's this formula or how do I explain something, do you think it might matter if it was, what is the formula compared to another formula, how do you explain it?

Nick Yeah, it would feel different because if it's an actual piece of knowledge then... You might think, oh, I should really know that but I don't and I haven't got much time so I'm going to ask them directly. You might feel a little bit bad but you've got to do it. And then if it's about a way of teaching something, well, that's something that we're expecting to be learning more so this year than actual subject knowledge.

Int 56:14 Okay. And again, to go back to the SKE work last year, if you think about some of the things that maybe were effective for you or significant or you liked, and maybe some things that you didn't like. If you were in some way allowed to influence how the course was reshaped or redesigned, what would you want more of or what would you want less of in terms of things that were effective for helping you develop your physics understanding?

Nick I think there should be more emphasis on, right, this is the current National Curriculum, these are the topics, this is what's taught today in school, go away and learn this to the best of your ability. We're going to teach you it this year, but... And then maybe have like, right, two months in, four months in, is there anything else you want to learn in addition to that, so that it's very black and white, clear cut, right, this is what you're going to be taught on the scheme and this is what you're going to be teaching kids in schools, so there's no grey area then. And there's obviously different exam boards and they pick and choose exactly which topics they want to teach and how they want to teach them.

Int 57:26 So what's the grey area? You mentioned there's no grey area here. What is that grey area?

Nick Just like if there's stuff that isn't taught on the scheme... Because I think we didn't do any astronomy last year, did we?

Int 57:38 Right, yes.

Nick But it is on the National Curriculum and some schools do teach it. So I feel now that I've got to go and find out exactly what all the planets are and the mechanics of how they move and suchlike. So I'd like it a bit more tailored to what's expected of the teaching in schools.

Int 57:58 Right. And would you want more or less or the same opportunity for explaining to others or microteaching or whatever it might be? Or are there other activities you think, oh, I want more of that type of approach?

Nick Hmm... I think more sort of like mini assessments, like ones that... Not formal assessments, as in you're failing or you're... Just like in class, like the test that we did the other day with the Key Stage 3 general science audit, that sort of thing, so you build your confidence that way then. But then that has to be supplemented with... Because you can fall into that trap of just learning stuff for tests, if you know what I mean. So just supplement it with maybe more lectures, maybe a broad spectrum, just to cover everything a bit more.

Int 58:55 Okay. Would you want more of that microteaching type stuff or was there enough for you?

Nick I think probably I wouldn't mind a little bit more. I mean, I know you're constrained by time, so obviously more content and more microteaching, it's obviously a lot more work. But

more microteaching but perhaps not as broad a topic for... Instead of for a group, maybe do it for an individual, just do it on something small and like do it for a less amount of time, maybe ten minutes or...how long were they anyway?

Int 59:29 They were quite... Was it 45 minutes?

Nick Yeah, 45 minutes, yeah. So maybe just 15, 20 minutes for one person teaching a smaller thing but have more of them. I reckon that would help.

Int 59:40 Right, okay. And finally, is there anything that we've not touched on or covered that you think I should know or might be useful for me to know in terms of what's effective for supporting your physics subject knowledge development?

Nick What could help me out, what could help us out?

Int 1:00:01 And there doesn't have to be anything but I'm giving you an opportunity in case there's anything that hasn't come up that you think you do want to share anyway.

Nick I just think like so far, we're two weeks into the PGCE and I'd like to have seen something that said, right, this is the National Curriculum of physics, bang, bang, bang, bang, and these are the different exam boards and this is what schools can choose, that sort of option, just so it's there in black and white in front of you. Even if some people have already researched it themselves and they already know it, it reinforces their confidence then, doesn't it, because they can look at it and go, oh yeah, I know about that, I know about that. Yeah, and then I don't think we've actually had a list of what is expected of us in terms of subject knowledge.

Int 1:00:44 Does that worry you?

Nick Well, not worry but it's just a little thing, like a to do list. I've got a to do list always on the go and it's just one of those things, you've got to think, right, well, I'm going to have to check this out at some point and find out, because then it might be something that pops up, like astronomy, where... I know we did learn it last year. I haven't really looked into it too much yet myself so I'm going to have to get my head in the books and do all the stuff we were discussing.

Int 1:01:14 Do you feel confident about doing that, do you think, or not confident?

Nick Yeah, yeah, yeah. Normally like textbooks or revision guides are quite competent in the way they describe and explain stuff, so... And there's always the knowledge of the people round here and there's a couple of people on the course who are astrophysicists, so if they haven't got the knowledge then... [Laughter] mind you could say that about oceanography. Don't ask me about that [laughter].

Int Thank for very much for that. That's really interesting for me so thank you very much. I do appreciate your time.

[End of Transcript]



## I. Cohort 1 focus group discussion extract about identity as a scientist

- ANDY      New scientists like... obviously you've got Brian Cox.
- BEN      Is he a scientist or is he a science communicator?
- ANDY      Ah.
- BEN      He's actually a scientist isn't he?
- ANDY      Yeah.
- BEN      He's a professor so he must be alright.
- ANDY      I remember watching the Royal Institute lecture that he gave and that was – funnily enough it was the stuff we'd been covering on the SKE, so I was like sitting there going "It's that, that, that, that".
- BEN      Was that the quantum one?
- ANDY      Yeah.
- BEN      It was recently at the royal society, royal institute.
- ANDY      Yeah. And he was talking about particles and[
- BEN      [Yeah it was a double whammy of Brian Cox wasn't it?
- ANDY      Yeah.
- BEN      (Inaudible 0:27:40).
- Int      0:27:42 Yeah he's a bit all over the place at the moment.
- ANDY      You should've heard Andrew before. Yeah I think it's important that we have popular scientists, real people.
- BEN      Is this physics teachers of the world in general?
- ANDY      You know, if sitting there telling kids "I'm a real person, I'm not packed away in a box once you go home."
- Int      0:28:08 So how does that relate to this, to your picture that you're trying to build up?
- ANDY      So it's like... it would be... I don't know, like *careers* in science?

NICK I think that's quite misleading isn't it because 99% of people who get qualifications in science aren't going to be media friendly science communicators like Brian Cox although they're going to be doing proper science jobs somewhere doing research, doing applied stuff.

BEN He is a particle physicist?

NICK Yes. (Overspeaking 0:28:42).

BEN He is legit, he is a legit scientist.

NICK Yeah he is yeah. But if he was doing more – like Attenborough, Attenborough doesn't do any science (inaudible 0:28:51).

BEN Yeah, he's not a scientist[

ANDY [No, he's a journalist that's the thing. That was in the Key Stage 2 thing, David Attenborough as a *famous scientist*; he's *not* a scientist. Okay he does a lot of stuff that has science in[

BEN He got about ten PhDs though, that made him a scientist.

Int 0:29:14 No he doesn't actually, he's got a degree. I don't think he's got anything[

BEN thought he got loads of honorary ones that[

Int [0:29:17 He's got lots of honorary ones yeah. What would he have to do then for him to be a scientist in your eyes?

ANDY For him to be a scientist[

NICK [He'd have to be doing some research[

ANDY [Yeah research. He would have to be doing some sort of investigation[

BEN [Does that mean you're not a scientist then?

NICK I'm not a scientist, no way, because I'm a science *teacher*; it's something completely different.

ANDY No but deep down – you know, we all did our degrees in science.

BEN Yes, that was (inaudible 0:29:47: a trial(?)) in undergrad science

ANDY But there always be a part of you that's a scientist.

BEN I was in Spain counting ants going past the floor, and I did that for an hour and then decided it was boring and made up my data, sunbathed for two weeks (laughing).

ANDY Unfortunately some of us weren't so lucky sitting in a shared laboratory waiting for a machine to finish[

Int [0:30:08 So are you all scientists? So and I mean Nick you're quite clear you're *not*?

ANDY I'd say I was a scientist. I've still got that drive in me to do[

Int [0:30:19 So are you a scientist?

NICK I [want to be an astronaut but that doesn't *make* me an astronaut

ANDY [No. I don't know. It's kind of... it goes back to what is science, what's[

Int 0:30:34 Because if you're saying David Attenborough's *not* a scientist then in what sense are *you* a scientist if he isn't?

ANDY Yeah. I don't know...

BEN I think if you're not doing something *new* you're not really a scientist. But yeah I'd say you need an element of *originality* to what you're doing in a scientific field, (overspeaking 0:30:59).

ANDY Yeah but you've got laboratory technicians, people who are working in labs, they're still – they'd still be considered scientists although they're doing the same thing day in day out. They're using instruments[

BEN [I'd say they're a lab technician rather than a scientist. I know what you mean, but people in hospitals are called scientists because they were a white jacket, it doesn't make them, if you're being strict about your definitions. (ABNFocusGroupL221-288)

## J. Cohort 1 focus group discussion extract about elements of subject knowledge

- BEN Because you can have these things [statements 2 and 5] but if you've got no subject knowledge [referring to statement 1] you're not going to – if you don't know any physics you're not a physics teacher are you?
- ANDY No.
- BEN Whereas you can still have all of this [referring to statement 1] and none of this interesting stuff [referring to the other statements], although my physics teachers, that's pretty much what they were, and would just write that [referring to statement 1] on a board for people to copy and you're still a physics teacher. Not a necessarily good one but you're still a physics teacher. Without that [statement 1] you're not a physics teacher you're just a guy...
- NICK Talking rubbish (laughing)
- BEN Banging stuff together.
- Int 0:38:22 That's interesting. Alright, so have I got that right then? You're saying that it's possible to not have this [statement 1]? Is that what you're saying? And have this [statements 2 and 5]?
- BEN Yeah but you'd just be a dancing monkey or something.
- ANDY Yeah.
- Int 0:38:33 I see. So I could take away number one and if you didn't have number one then what? You're not a physics teacher or not a really good physics teacher?
- ANDY You wouldn't be a particularly effective physics teacher would you?
- NICK You'd be like a supply teacher with some worksheets someone has left you
- Int 0:38:48 But you can have number one and what? If I take away these two – so two and five – is that viable what's left?
- NICK It is. In that situation you're a *teacher* going into a class that's rapidly going to deteriorate into chaos and the kids are not going to pay attention because they're not switched on, it's not relevant to their lives, they're not engaged.
- BEN I don't know. I had a guy at [...] at college, and he just had loads of this number one, the high level of broad content, and he just wrote it on the board. It just went from his brain

onto the board and then from the board into our books and we all scraped through amazingly

Int 0:39:31 So he didn't have two and five, there was no evidence of two and five here then.

ANDY My A Level physics was a little bit different, it was the other way. Mine was like – my teacher had worksheets that had like booklets off the net and he literally just sat there and talked us through them. It wasn't relevant to our lives as such, if you know what I mean. I know personally it is but sitting there just explaining it away.

BEN Do you think you'd have done better if it was (inaudible 0:39:59)?

ANDY I think it might've been a bit better because it was linked to the – it was very historical, it was loads of content in it, and it was explained, but it didn't seem *relevant*.

Int So if I take away three and four what difference does that make, or would that make, for you?

NICK I think three and four, the historical and development of ideas and including the bit about lifestyles and key figures, they're sort of niceties that bolt on to the bottom and feed back to what could make a good lesson, what could make a good teacher; they're not *essential* but as you develop your teaching career your subject knowledge will improve in terms of your knowledge about historical figures and their impacts on science. And because of that knowledge increasing you'll be able to create more engaging lessons. So they do feed in to two and five but they're not essential.

BEN And they're strongly linked to the context sort of idea aren't they that they make it real, the concepts real. Like if some old guy is sat there in a lab doing this at some point because he didn't realise or because they had an inkling that it might be the case. I think it makes it a bit human as well (ABNFocusGroupL383)